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Date 1/5/97

A CHECKLIST ASSESSMENT OF DUNE VULNERABILITY AND PROTECTION MEASURES IN WALES U.K.

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CONTENTS

APPENDIX 1 : RAW RESULTS

APPENDIX 2 : NOTES FOR USE WITH THE COASTAL SAND

LISTS OF FIGURES

LIST OF PLATES

LIST OF TABLES

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Abstract

There has been little success in developing a method that can quantitatively assess the vulnerability of a dune system and the effectiveness of protection measures. A checklist system has been devised that attempts to overcome this problem. The analysis consisted of assessing a series of 54 parameters which are organised into the following five sections :

A) Site and Dune Morphology (8 parameters).
B) Beach Condition (9 parameters).
C) Surface Character of the Seaward 200m of the Dune System (12 parameters).
D) Pressure of Use (14 parameters).
E) Recent Protection Measures (11 parameters).

Summation of the 43 parameters (A-D) gives a Vulnerability Index (VI). The remaining 11 parameters relate to recent protection measures (E), which when summed give a Protection Measure Index (PM). During pilot stages of the checklist development the process proved to be an extremely workable and rapid procedure to assess the balance between dune vulnerability and protection, the relationship being calculated with a Vulnerability/Protection Measure Index (VI/PM). The checklist was used to assess the major dune systems of Wales. The total vulnerability range was from 4.3% at Broadhaven to 65.1% at Morfa Dyffryn, with an average of 39.1%. The protection index varied from 13.6% at Morfa Bychan to 68.2% at Conway, with an overall average of 43.7%. Scores however, need careful interpretation as low protection indices do not necessarily mean inappropriate management strategies. This checklist approach improves the levels of objectivity in analysing coastal dune vulnerability and protection measures, and as such provides a firm base on which important management decisions may be made.

CHAPTER 1

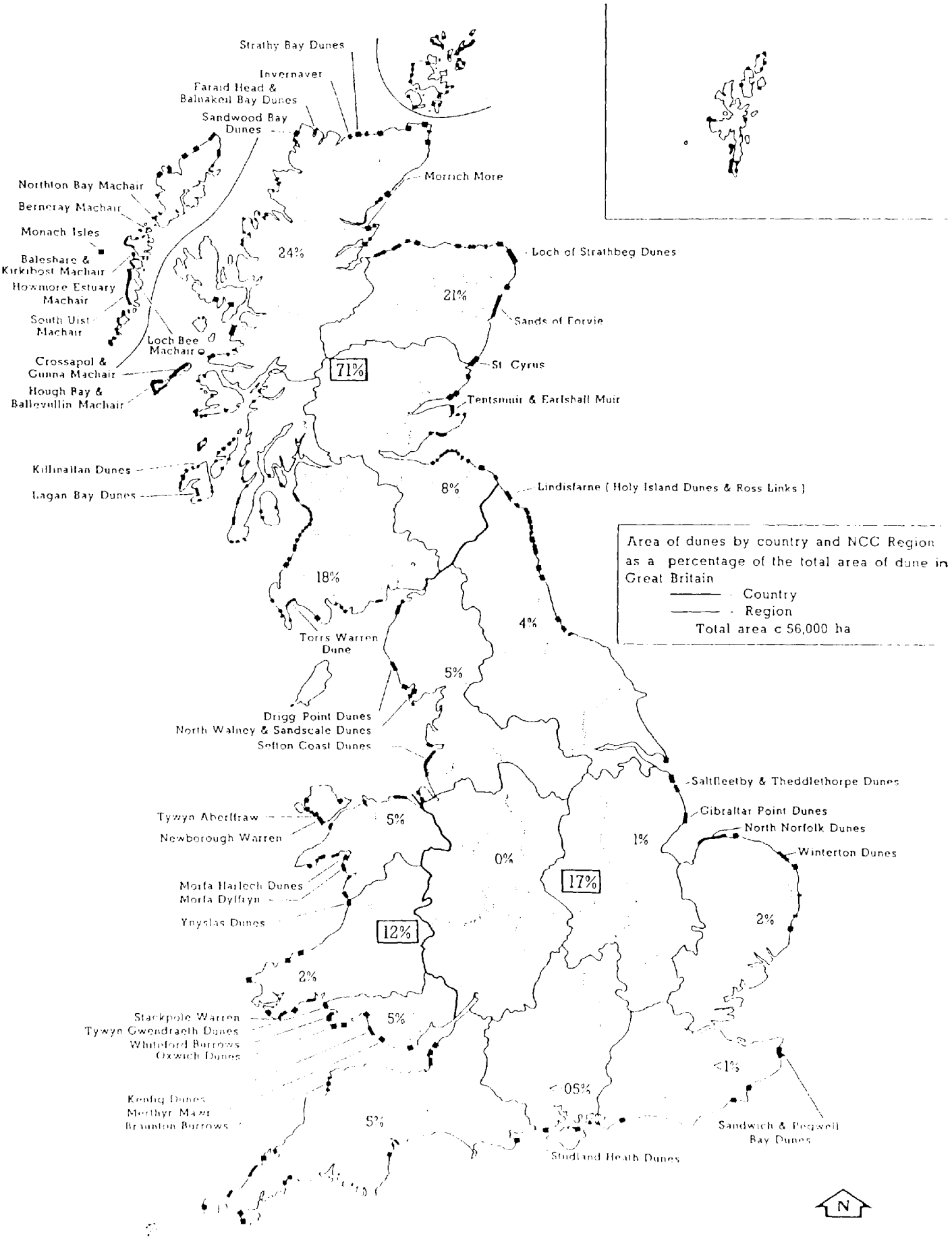
INTRODUCTION

The coastal zone of Wales supports a wealth of natural habitats. Only about 30% of the coastline does not qualify for some form of protection or landscape designation. The other 70% has a variety of UK designations including statutory protective designations of important biological and geological features and designations designed to preserve some outstanding coastal landscapes (SMITH *et al*, 1995).

Excluding afforested areas, the surviving sand dunes in Wales cover an area of approximately 6406ha, with losses to afforestation totalling about 1,772ha. It can be seen that the majority of sites are concentrated to the north and south of the principality. The total figure represents 12% of the total area of dune to be found in Great Britain (FIG 1; DOODY, 1985).
Today about 83% of the surviving Welsh sand dune resource is protected under UK legislation because of its biological interest. Many sites are recognised to be important in a European context, and around half of the total area (3,060ha) has been selected as qualifying for Special Areas of Conservation (SAC) designation. All the proposed sites support comparatively large areas of the 'fixed dunes with herbaceous vegetation' as a priority habitat (e.g. Kenfig NNR, Mid Glam), which are judged to be particularly endangered in Europe. The European importance of Welsh sand dunes is further highlighted by the fact that all EC Habitat Directive Annex II coastal plant species in Wales, including the vascular plants, *Lipanis loeselii* and *Rumex rupestris*, and the bryophyte, *Petalophyllum ralfsii*, are sand dune inhabitants (SMITH *et al*, 1995).

FIGURE 1

DISTRIBUTION OF NATIONALLY IMPORTANT SAND DUNES IN GREAT BRITAIN



Sand dunes play a significant role in providing habitats for a wide variety of fauna and flora. This is brought about by the generally high level of habitat diversity that is exhibited on coastal dunes, for generally there are 4 possible axes of variation within the systems. These being:-

1) Along successional gradients
2) Across transitions to other coastal habitats
3) Variations to inland vegetation
4) Along gradients of soil moisture.

The diversity of a site is often directly related to its naturalness. Indeed the more natural sites not truncated by development or isolated from coastal processes tend to span a greater range of conditions, and thus support a greater variety of vegetation. There are however sites which would score high on naturalness but low on diversity (RADLEY, 1994).

Diversity is but one of a number of factors that Radley (1994) has listed to evince the value of coastal dunes. The other factors are:

a)**Rarity**; In connection with their geomorphology, vegetational communities and animal species. Viewed in geological time, coastal dunes are transient, mobile formations that stand a relatively low chance of being preserved in the stratigraphic column. Dunes react to environmental change on a variety of time scales, especially to variations in sediment supply and to sea-level change. However, the geologic role of dunes should not be dismissed as they play a major part in coastal evolution, supplying shoreface deposits and sealing lagoons (CARTER, *et al*, 1990).

Some plants and animal species have become specialised to live almost exclusively in dune habitats, such as the Little Portland moth (*Actebia praecox*), and the plant species *Gentianella uliginosa*, which is mostly limited to damp slacks. This is a rare species and is declining throughout its range, mostly due to afforestation and in response to stabilisation (JONES, *et al,* 1995).

b)**Fragility**; Ranwell (1977 p 14) wrote of fragility, "This criterion reflects the degree of sensitivity of habitats, communities and species to environmental change". In some ways dunes are extremely robust. Most of their vegetation has a remarkable capacity to recover from disturbance, and the dunes own dynamic character enables them to survive stress. In other ways through dunes do show a degree of fragility. Dunes themselves are somewhat ephemeral structures, and interface with other coastal processes, sometimes at a considerable distance, can easily precipitate or accelerate erosion. The dune vegetation can also be vulnerable to nutrient enrichment; continued and concentrated wear; and loss of diversity as a result of over zealous protection measures.

Perhaps the most fragile aspect of a coastal dune system is the subjective and perhaps some what unquantifiable quality of 'Naturalness'. This aspect can even be easily destroyed by developments, whose direct ecological impact may be negligible. It can also be destroyed by some forms of conservation management, such as the digging of ponds for Natterjack toads.

c)**Education**; Coastal dunes can be superb ecological classrooms. This is effectively demonstrated in Wales by the intensive educational use made of Oxwich NNR (Gower) and

the site at Ynyslas NNR (Dyfed), where a Field Studies Officer taught 5,189 students in 1992 (YNYSLAS STUDENTS GUIDE, 1992). The reason these sites are so popular is that ecological principles, such as succession, and competition dispersal are demonstrated with unusual clarity. The dunes also lend to the teaching of geomorphology and geography.

d)**Intrinsic appeal**. There is little doubt that people appreciate the recreational appeal of dunes, for they often adjoin good bathing beaches, providing displays of wild flowers and topography that encourages a sense of space and privacy.

Wales' coastal dune systems are valued for each of the factors indicated. As previously noted, because of their value 83% of the sites in Wales have received some sort of designated protection. Unfortunately in the UK, there has been a somewhat *ad hoc* approach to dune management. This has left some of these valued landforms wonderfully unspoilt (usually where traditional grazing has continued in the absence of pressure from recreational needs), while others have been destroyed or damaged through afforestation, intensive recreational use or development (HOUSTON, 1992).

Good management policy requires a balanced scientific assessment of the environment. Therefore a sound environmental data base is essential to the satisfactory solution of environmental management problems which aim to integrate human and natural systems (WILLIAMS *et al*, 1993). In order to try and redress some of these difficulties, a Dune Vulnerability Checklist has been devised to provide a data base capable of use as a

TABLE 1 : COASTAL SAND DUNE VULNERABILITY CHECKLIST

SCORES>

SECTION A - SITE AND DUNE MORPHOLOGY

	0	1	2	3	4
1. Orthogonal fetch	short [ ]		medium [ ]		long [ ]
2. Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [ ]
3. Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	> 1 [ ]	>.1 [ ]
4. Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [ ]	<.1 [ ]
5. Maximum height of dunes (m)	>25 [ ]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a. If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [ ]
6b, If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c. If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7. Relative total area of wet slacks	moderate [ ]		small [ ]		none [ ]
8. particle size in foredunes	-----	-----	-----	-----	-----
compare particle size with index	-----	-----	-----	-----	-----
Phi sizes =	< .1 [ ]	0 [ ]	+1 [ ]	+2 [ ]	+3 [ ]

TOTAL SCORE / PERCENTAGE

SECTION B - CONDITION OF THE BEACH

1. Width of inter - tidal zone (km)	>.5 [ ]	>.2 [ ]	>.1 [ ]	> 05 [ ]	<.50 [ ]
2. Sand supply input	high [ ]		moderate [ ]		low [ ]
3. Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [ ]	>25 [ ]	> 50 [ ]
4. % foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
5. Dune cliff as % dune height	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6. Breaches in seaward face	none [ ]		some [ ]		many [ ]
7. Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [ ]
8. Seaweed on upper beach	much [ ]		some [ ]		none [ ]
9. Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		none [ ]

TOTAL SCORE / PERCENTAGE

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

1. % System surface unvegetated	<10 [ ]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2. Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3. Sand blown inland from system	little [ ]		some [ ]		much [ ]
4. Saltwater invasion of dunes	none [ ]		some [ ]		much [ ]
5. % new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [ ]
6. % breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [ ]
7. % seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8. If recent sand deposition assess colonisation by marram	much [ ]		some [ ]		none [ ]
9. % impenetrable cover	some [ ]		little [ ]		none/much [ ]
10. Frontal change since 1940	advance [ ]		oscil. [ ]		retreat [ ]
11. Vegetation change since 1940	inc. [ ]		oscil. [ ]		decr. [ ]
12. Relic quarries in frontal (200m)	one [ ]		small [ ]		large [ ]

TOTAL SCORE / PERCENTAGE

SECTION D - PRESSURE OF USE

1. Visitor pressure	low [ ]		moderate [ ]		high [ ]
2. Road access	one [ ]		moderate [ ]		good [ ]
3. On dune driving	none [ ]		some [ ]		much [ ]
4. Horse riding	none [ ]		some [ ]		much [ ]
5. Path network density	low [ ]		medium [ ]		high [ ]
6. Paths incised	little [ ]		moderate [ ]		deep [ ]
7. Commercial camping	little [ ]		some [ ]		much [ ]
8. Dispersed camping	little [ ]		some [ ]		much [ ]
9. Housing	little [ ]		some [ ]		much [ ]
10. Owners	one [ ]		some [ ]		many [ ]
11. Main owner/ manager	protection agency [ ]		public [ ]		priv. [ ]
12. commercial / random extraction	none [ ]		some [ ]		much [ ]
13. Grazing by cattle/sheep/goats	none [ ]		some [ ]		much [ ]
14. Rabbit population	small [ ]		moderate [ ]		large [ ]

TOTAL SCORE / PERCENTAGE
VULNERABILITY SCORE AND INDEX

SECTION E - RECENT PROTECTION MEASURES

1. Surveillance and maintenance	none [ ]		some [ ]		much [ ]
2. % area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3. Controlled parking	one [ ]		some [ ]		all [ ]
4. Horse riding controlled	none [ ]		some [ ]		all [ ]
5. On dune driving controlled	none [ ]		some [ ]		all [ ]
6. Managed paths	one [ ]		some [ ]		all [ ]
7. Sand traps	few [ ]		some [ ]		many [ ]
8. Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	50 [ ]
9. Information boards	none [ ]		some [ ]		many [ ]
10. If marine erosion - protection work	neg. [ ]		some [ ]		much [ ]
11. Protection by legislation	weak [ ]		moderate [ ]		

TOTAL SCORE / PERCENTAGE
PROTECTION SCORE AND INDEX

management aid (TABLE 1). The checklist is an objective procedure which summarises the condition of the system, being able to reflect changes initiated in the past and those induced by contemporary environmental factors. Due to this achievement of site summation the data obtained is able to form the basis for dune management strategies aimed at achieving sustainable usage.

CHAPTER 2

DUNE FORMATION

At mid to low tide, sand is exposed to the air and dries and can be blown off the beach by onshore winds, where under suitable conditions it can accumulate to form coastal dunes.

2.1 Sand Supply

The distribution pattern of sand around our shores is largely a legacy from the last glaciation which ended some 10,000 years ago. The sand is derived from 3 sources by a variety of agencies :

1 From land via rivers ;

2 From coasts via wave action and wind erosion ;

3 From the sea bed via currents, storms and dredging for beach - feeding purposes.

The river source was initially important, but is now of less significance since river beds have become graded, and dams have stopped sediment input. The coastal source has also diminished, as many sections of the coast are protected by sea defence structures (RANWELL and BOAR, 1986). The immediate source of sand for dune formation is in fact the shore.

The foreshore is defined as the zone between mean low water and the mean high tide line (OXFORD DICTIONARY, 1994). Although most of the foreshore remains permanently wet, higher levels dry out sufficiently to supply up to 10 -20% of wind-blown sand for dune building (KRUMBEIN and SLACK, 1956 and WILLIAMS, 1979).

The backshore is defined as the zone from the mean high tide line to the dunes (OXFORD DICTIONARY, 1994). This zone supplies up to 80% of the sand for dune building as it is only submerged during storms, or exceptionally high tides, on 2 or 3 days a month at most (CARTER, 1988). Therefore the width, length and height of this backshore zone is an important key to the continued growth of a dune system.

2.2 Sand Movement.

Given a supply of beach sand, the next requirement to initiate dune building is the sufficiently common occurrence of winds. However, even if the sand is dry, the onshore wind cannot transport it until a certain threshold velocity is reached capable of dislodging sand grains at the surface. This shear velocity is defined as:

$$u_*t = A[gd\ (p_s - p)/p]^{0.5}$$

where A is the square root of the Sheilds Function, taken as 0.1 for air and dropping to 0.08 during saltation.

g is gravitational acceleration

d is mean grain diameter

p_s is sediment density

p is air density (SHERMAN, 1990).

For average-sized sand grains this occurs with wind speeds of approximately $4ms^{-1}$ (BAGNOLD, 1941). Once restraining forces are overcome the particles then either roll or saltate downwind. Upon landing, the saltating grains may dislodge further grains which can result in large numbers of grains moving. However, really substantial sand movement is only accomplished by high wind velocities, as above the threshold velocity ($4ms^{-1}$), the rate of sand flow varies as the cube of the wind velocity (FIG 2, BAGNOLD, 1954).

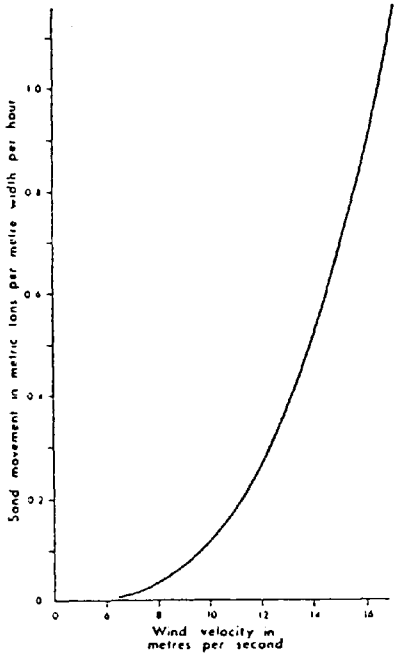


FIG 2 Relation between Wind Velocity and rate of Sand Transport

2.3 Sand Deposition.

Sand may be transported considerable distances alongshore where the winds are parallel to the coast, but in most cases deposition occurs within a short distance (CARTER, 1988).

Deposition occurs only when obstacles in the wind-run disturb the flow and create shelter. These obstacles could be in the form of tidal litter ; boulders, driftwood or clumps of vegetation. Small shadow dunes then form behind these obstacles with tails stretching - out downwind (HESP, 1981).

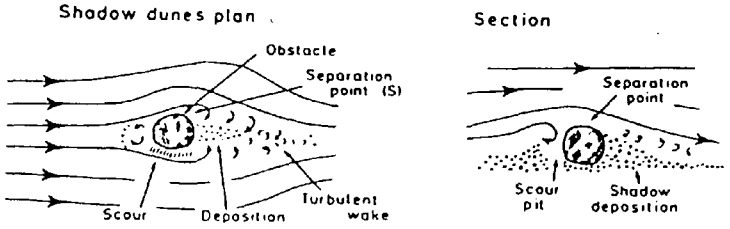


FIG 3 Shadow Dunes

Once sand has accumulated over the backshore tidal litter, the stage is set for a sequence of events that can, under favourable circumstances, ultimately lead to the formation of a coastal dune usually up to 10 or 15m high, on British coasts.

2.4 Vegetation.

Plants play an essential role in the formation of dunes. The first plants to colonize the

backshore are annuals such as Sea rocket (*Cakile maritima*) and Saltwort (*Salsola kali*). These reproduce from comparatively large, double - or single - seeded fruits which can float for at least a week (IGNACIUK and LEE, 1980) and are tolerant of long periods of immersion in sea water. They germinate rather late (May), but grow rapidly to form plants up to 1m in diameter and 0.5m in height, depending on buried tidal litter and sea spray for their nutrients. These plants trap wind-blown sand in hummocks; with Sea rocket (*Cakile maritima*) being capable of raising the local sand level by as much as 1m in one growing season. Even in winter their dead stems help to retain some sand. (RANWELL and BOAR, 1986). However, these strandline annuals are not an essential precursor to dune formation. Providing sand levels are high enough, dune-forming grasses can colonize the back shore directly.

2.4.1 Dune-building Grasses.

The chief sand-building plants on European coasts are grasses. Dune growth is most frequently initiated by Sand couch-grass (*Agropyron junceiforme*), which is tolerant of salinities up to 3.5% sodium chloride, providing tidal inundation lasts for only a few hours. The most important dune building grass species however, is the Marram grass (*Ammophila arenaria*), which in contrast can only tolerate 1% salinity, making it less successful at the strandline level than Sand couch- grass (*Agropyron junceiforme*) (RANWELL and BOAR, 1986).

These species propagate by both seed and rhizome fragments. The seedling roots of Sand

couch - grass (*Agropyron junceiforme*) can reach down 1cm to more or less permanently moist sand within 10 days. Subsequent growth of short and then long rhizomes with the production of short tufts at intervals, enables the plant to retain a strong hold and to trap a low sand mound. Even if the top growth is severed by storm tides, the base of the plant may still persist and regenerate (HARRIS and DAVY, 1986).

In addition to horizontal growth, rhizomes and shoots of these species are capable of vertical elongation in response to sand burial. It is these singular characteristics which make these dune grasses so valuable in raising sand levels at the coastline. Where net sand accumulation is 23cm or less per year, Sand couch-grass (*Agropyron junceiforme*) can keep pace with it. Where accumulation is from 25cm to 50cm per year, vertical rhizomes extend and carry the new shoots to the superior surface level in the following year. Where sand accumulation significantly exceeds 60cm per year Sand couch- grass (*Agropyron junceiforme*) is inhibited. The only species which is able to survive accretion rates of up to 1m per year is Marram grass (*Ammophila arenaria*), as this is the only species which has a virtually unlimited capacity for both horizontal and vertical rhizome growth (RANWELL and BOAR, 1986).

These dune building grasses are able to trap sand, because a dense strand of vegetation creates a false ground surface, which leaves a pool of still air below it.

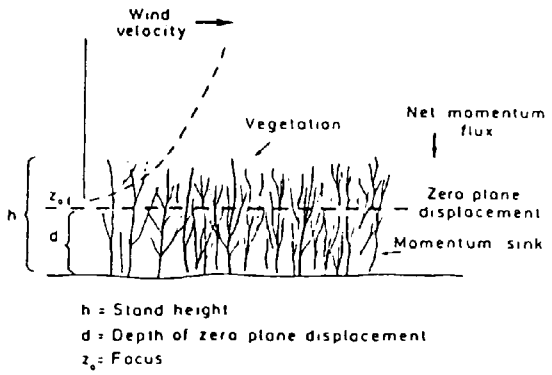


FIG 4 Wind Velocity profile over Dense vegetation Stands

This elevated aerodynamic boundary is known as the zero plane displacement, and is located around two-thirds of the vegetation height. The residual downward momentum flux then becomes absorbed within this still pool. These down-draughts are ideal for sedimentation, thus particles from the up wind enter the air pool and become trapped. The most rapid sedimentation takes place near the leading edge of the stand, which then creates a wedge-shaped foredune within the canopy.

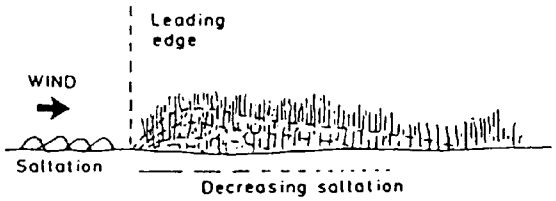


FIG 5 Sedimentation in the presence of vegetation

2.5 Dune Morphology.

The shape of a bare sand dune in the desert (barchan dune) is that of a shallow windward slope, with a steep leeward slope of about 32 degrees (the critical angle of rest of loose dry sand; STEERS, 1964). However, a vegetated coastal dune has a cross-section which is just the opposite; having a relatively steep windward slope and a long shallow leeward slope. But unless the dune is completely covered with vegetation, the wind will try to convert the steep windward face to a shallower profile. The presence of vegetation actually transforms the natural tendency towards a barchan form into an inherently unstable shape (RANWELL

and BOAR, 1986).

As the dune gains in height, wind velocity over the crest steadily increases, especially if the dune has a sharp crestline, as this causes acceleration of up to 1-2 times the freestream velocity (CARTER, 1988). Here erosion tends to counterbalance accretion and as a result, there is a natural height restriction on the growth of a dune, which varies according to sand supply, climate and local topography.

European dunes may rise to a height of around 90m, as on the Coto Donana in Spain. However, on the colder and somewhat stormier British coasts, dunes rarely reach more than 30m in height, although most are frequently not much more than 15m high.
It has been estimated that for a typical coastal dune to reach this full mature height, it would take approximately 75 years (RANWELL and BOAR, 1986).

CHAPTER 3

THE DUNE ENVIRONMENT

3.1 Formation of the Dune and Slack System.

Whatever type of coast is considered, whether it be prograding with an abundant sand supply or eroding with a limited sand supply, coastal dune growth is initially in a linear or curvi-linear manner parallel with the strandline. It may then either stabilize at a low level, erode and recycle as in a small bay, or continue to accumulate as in open coast sites where sand supply is abundant (RANWELL, 1972).

If the coast is prograding, a series of ridges are formed in sequence with the youngest to seaward; these dunes then become stable *in situ*. At an eroding coast where sand supply is limited, the seaward ridge grows to a maximum height and then by local erosion and deposition moves landwards, either as a parabolic dune or as a complete dune ridge. This type of system may undergo centuries of instability before the sand is permanently fixed by vegetation (BOORMAN, 1978).

The coastal dune's seaward growth is restricted by storm tide height, which can undercut the dune to form a near vertical seaward face, such as that encountered at Kenfig NNR (Mid Glam). Once this condition develops in regions where there are strong onshore winds, the coastal dunes windward face continues to erode. Sand then accumulates on the grass-covered

leeward slopes, effectively moving the dune back from the shoreline while it still continues to build to its maximum height. The process of erosion usually continues downward until the level of permanently wet sand is reached. This then produces a "flat-bottomed" dune valley or dune slack, which becomes colonized by its own characteristic vegetation (BOORMAN, 1978). On the western coast of Britain where prevailing Atlantic winds are on shore, this type of dune movement is a natural phenomenon which occurs quite independently of human disturbance.

Ranwell (1958) estimated that a coastal dune would take 50 years to reach its maximum height, and that its mean rate of movement landward would be 6.7m per year. Thus it would take approximately 70-80 years before a dune would have moved landward sufficiently for the development of new embryo dunes. Although to attain a degree of stability a longer time period needs to be considered.

3.2 Types of Dunes Systems.

Dune systems can vary in quite fundamental ways from each other, depending upon the topography and weather conditions under which they were formed. Ranwell and Boar (1986) recognised these geomorphological differences and subsequently classified coastal dune systems into 5 main types (FIG 6)

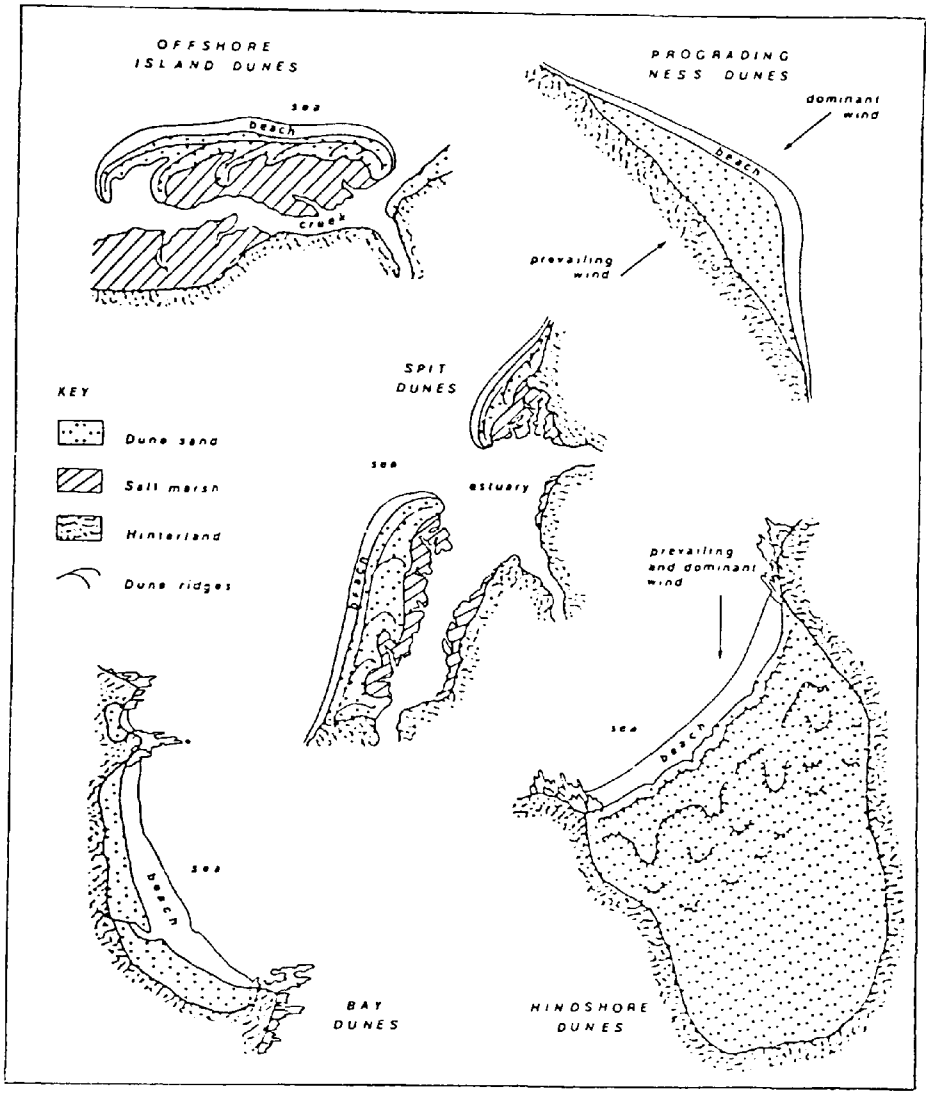


FIG 6 Types of dune systems after Ranwell and Boar, 1986.

Some dunes systems may have some characteristics of more than one type, some even being intermediate of types. However, it should still be possible to recognize where any dune system stands in relation to the following classes that Ranwell and Boar (1986) devised.

3.2.1 Offshore Island Dune Systems.

This type of dune system is not present in Wales. They are associated with offshore or barrier islands, like the island dune system off the Norfolk coast. Due to the exposed situations present at these systems they rarely develop high dunes. The systems are often situated on coarse, freely draining deposits of sand or shingle, formed under high wave energy conditions.

The smaller of these systems rarely develop fresh water slacks, but the hollows may have some tidally controlled brackish water influences where the dunes rest on highly permeable shingle. These island systems tend to extend in the dominant direction of the longshore drift, tending to be narrow in width and form an age series extending in one direction along the coast. Also due to the narrow nature of these systems some can be subjected to wave and tidal overwash from time to time.

3.2.2 Prograding Dune Systems.

Dune systems may build out, or prograde, from an open coast where there is an abundant

supply of sand, either from a very broad high level shore to seaward, or at an accumulation point simultaneously receiving sand by longshore drift from 2 directions. These conditions are more usually found on the eastern shores of Britain where the prevailing wind blows offshore and is in opposition to the dominant wind from another direction. However, there are some examples of this type of dune system found on the west coast of Britain, such as the dune systems of Crymlyn and Baglan Burrows (West Glam.). The seaward progression of such systems can be so rapid that the dunes do not have time to grow very high before their sand supply from the shore is captured by the next new dune ridge to seaward. The successive dunes and slacks then become stabilized *in situ*, forming an age series normal to the coast.

A Cuspate foreland dune system forms a link between a headland and a spit formed at the mouths of an estuary. These cuspate systems form at the mouth of large shallow sandy-floored lochs where again the sand supply is from 2 directions, the outer coast shore and the inner loch shore.

3.2.3 Spit Dune Systems.

Spits are one of the commonest types of sand dune systems. They form as sandy promontories at the mouth of estuaries, such as at Whiteford Burrows (West Glam). Usually one of the 2 estuary mouth spits is larger than the other, depending on sand supply and the dominant direction of longshore drift. They often form a fan-like series of dune ridges and intervening slacks, with the handle of the fan tied to the mainland. However it must be noted

that these systems are highly varied in shape and size.

3.2.4 Bay Dunes.

Bay dunes are the most frequent of all dune systems. Sand trapped within the relative shelter of the embracing headlands is often limited in supply and is insufficient to form more than a single narrow band of coastal dunes. Sand disposition within a bay system is controlled by the shelter effect of the local topography in relation to dominant winds. Bay dune systems are frequently associated with a moderately indented rocky coastline like that of South Wales, an excellent example being the dune system found at Stackpole (Pembroke). Tidal litter from nearby rock shores in the form of seaweed is not only often abundant, but tends to accumulate in the shelter of the bays, favouring strandline vegetation growth.

3.2.5 Hindshore Dune Systems.

These dune systems are found on extensive sandy coasts where the prevailing wind is also the dominant one. Vast masses of sand are driven landward in huge arcs or ridges which continue to erode until they are flattened by the wind several miles inland from the shore. A good example of this type is the dune system of Newborough Warren in Anglesey.

As each coastal dune develops to maturity within a century or so, it moves back under the

influence of wind erosion and continues to move either as a single huge eroding ridge or as an irregular chain of parabola-shaped dunes budding off from ridges. The damp dune slack level forms a basal surface over which successive waves of dunes pass to their final point of stabilization. In these circumstances, the age series becomes obscured by the turnover of sand and the whole dune landscape may become a complex web of dunes and slacks as the structure is broken up by varying winds from different quarters. Extreme forms of hindshore dune systems called "machair" are found locally in Western Scotland. They are formed as a result of exceptionally strong winds which limit severely vertical sand dune growth. Strong winds drive sand landward to form a blanket over the rock and peat bogs, sometimes carrying the sand to elevations of 100m or more. These systems are also often strongly affected by the grazing of sheep and rabbits.

3.3 Dune Ecology.

At first sight dune sand does appear to be a very inhospitable medium for supporting plant and animal communities, it has a low moisture-holding capacity and is generally poor in mineral nutrients essential for plant growth.

3.3.1 Dune Water Regime.

Because dune soils are coarse-grained, and loosely packed with relatively large intervening air spaces, they allow free water movement. These characteristics result in them having a relatively low field capacity (VAN DER MEULEN *et al.*, 1991), although the field capacity does increase with an increase in the soil organic material, as the soils develop and mature. For example, Salisbury (1952) showed that the field capacity increased from 7% in young dune soils to 33% in old mature dune soils. Drainage water moves downward under the influence of gravity to the permanent water-table that exists under most dune systems, often floating on a deeper layer of infiltrated seawater (BOORMAN, 1977).

A large dune system behaves as an isolated granular deposit. Due to this the water-table appears dome-shaped, ie highest near the middle of the system and lowest at the periphery (RANWELL and BOAR, 1986). For this reason, there is a variation in the relationship of the water-table to the soil surface, throughout the dune system. There are often areas of standing water (dune lakes) at the landward side of the system. This is where water from the dunes, meets water draining coastward from the land. Damp slacks develop with the

water-table near the surface, maintaining the soil some 30cm from the water-table at near saturation levels. This coupled with capillary rise, leads to fairly high moisture contents up to 50cm above the water-table (WILLIS, 1985). On high dunes when the water-table is out of reach to all dune plant species maximum root penetration depth is no more than 2m (RANWELL and BOAR, 1986). Here the moisture requirements of the plant species is maintained entirely by the amount of rainfall that the sandy soil can hold and the deposition of dew. As a result of the soil's open structure, it is a poor conductor of heat (VAN DER MEULEN *et al*, 1991), the temperature of the dunes drops rapidly from the surface downwards, so that even in mid-summer the internal dune temperature will cause dew to be deposited. In the summer months the effect of this dew on shallow rooted plants on the dune slopes is quite significant, as there can be an increase in soil moisture by as much as 0.9ml per 100ml of soil on a clear night (SALISBURY, 1952).

3.3.2 Dune Soils.

The soil changes considerably during the development of a dune system, there being very general trends with the progressing age of the system, ie. an increase of organic matter. The early dune stages have very low humus levels, but with an increase in plant biomass and stability, these levels become larger in later stages (Fig 7).

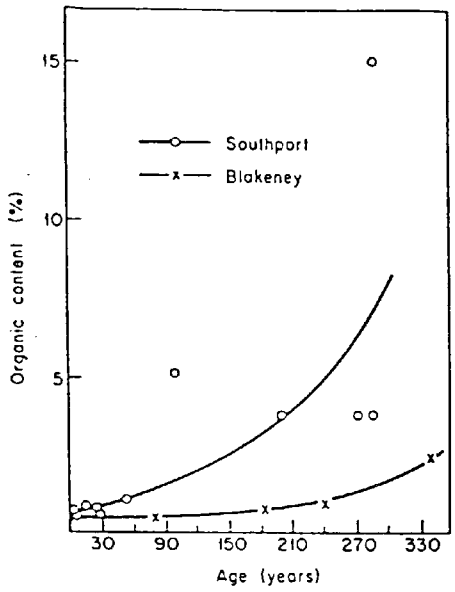


Fig 7 Changes in the organic (humus) content of sand dunes at Southport and Blakeney point, Norfolk, with ageing. (SALISBURY, 1952.)

The humus content also influences the soil pH, and with age there is a tendency for dunes to become more acidic (Table 2).

pH	Dune Type	Dune Age (yrs)
6.6 - 7.0	Early dune	0 - 20
5.0 - 5.5	Dune grassland	0 - 50
4.8 - 5.5	Late dune grassland	50 - 80
3.9 - 4.6	Dune heath	80 - 110
3.9 - 4.5	Dune heath	110 - 230
3.6 - 4.5	Dry heath	240 - 350

Table 2 Variation of pH with age in Sand dunes at South Haven, Dorset (SALISBURY, 1952)

However, the presence of carbonates, resulting from the weathering of mollusc shells, sometimes counteracts the influence of the humus, and some dune soils can give an alkaline reaction (EVANS and HARDY, 1970). Dunes which start with about 3% calcium carbonate become lime - deficient at the surface in about 200 years in the British climate, but, where the initial carbonate level is 10% or more, acid soils may not develop for many centuries (RANWELL and BOAR, 1986).

It is interesting to note that seawater contains every element that is essential for plant growth, and most, if not all of these elements are available to the plants via salt spray, sometimes in quite appreciable quantities (Fig 8).

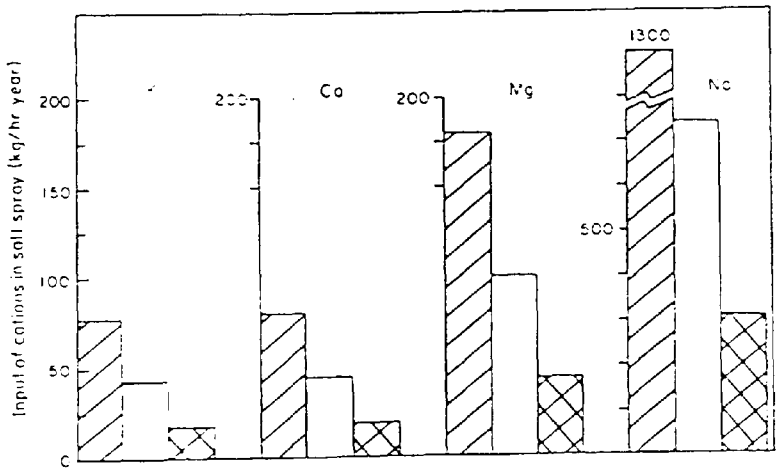


Fig 8 Estimated or calculated annual inputs (kg/ha/yr) of cations in salt spray falling on the front ▨, top ▢ and back ▩ of a foredune at Bodie Island, USA (VAN DER VALK, 1974).

In terms of the actual availability of mineral nutrients there is, if anything an overabundance, except for nitrogen (N), phosphorus (P) and potassium (K). However, it must be noted that once spray delivered nutrients are deposited on the sand surface, rapid leaching takes place, with the leach rate increasing with increasing grain size (HESP, 1991).

Obviously as one moves landwards the amount of salt spray fallout decreases, therefore one of the main sources of nitrogen and certain other nutrients for these increasingly landward sites, is that gained through airborne material. Although the quantities involved are small, in the nutrient poor habitat, of the sand dunes, these small quantities can have a significant effect. For example, it has been estimated that the nitrogen input per annum can amount to 9-19kg ha^{-1} (BOORMAN, 1977). Taking the top 25cm of the soil with a nitrogen content of 0.01% (ie the 1st dune ridge), the amount of aerial nitrogen washed down by the rain can range from between 1.5 and 2.5 % of the total per annum. The quantities of the other major nutrients occurring in the rainwater per annum were rather lower, eg P: 0.2-1.0 kg ha^{-1} and K: 2.8-5.4 kg ha^{-1}. Although these are small values, over a period of years this source could be quite significant, especially for lichens, that are able to take up nutrients from rainwater (BOORMAN, 1977).

The chemical properties and the nutrient status of the dune soil can however, be affected quite substantially by disturbance and human trampling. Evidence from a coastal site in Sri Lanka suggests that the nutritional status of sandy soil may be markedly influenced by human disturbance, the latter leading to more acidic conditions and lower levels of the major nutrients N, P, K, Ca (WILLIS, 1985).

3.3.3 Dune Fauna.

The fauna of the coastal dune is dominated by arthropods and vertebrates, particularly insects, birds and mammals. Arachnids are common, and crustaceans may be important near the beach, as the backshore and dunes represent one of the avenues of land colonization by crustaceans, especially talitrid amphipods and oniscid isopods (McLACHLAN, 1991). Molluscs and frogs also occur, but with the former preferring lime-rich soils (RANWELL and BOAR, 1986). However, it is the insects that are the most dominant, especially the orders Hymenoptera, Coleoptera and Diptera. Most larger mammals tend to traverse the dunes only temporarily for feeding or to gain access to the beach to forage (McLACHLAN, 1991), with the exception being the rabbit, where the moist cohesive sand, not far below the surface in British dune systems provides an ideal burrowing medium for the species (RANWELL and BOAR, 1986).

Due to their often high moisture content, dune soils may also support rich interstitial fauna, consisting of bacteria, fungi, actinomycetes and algae, along with the mesofauna, which may be important in both dune vegetation succession and in the decomposition of organic material in the sand. The bacteria and fungi are the primary colonisers of supralittoral and dune sands, exhibiting a landward succession (McLACHLAN, 1991).

Despite the fact that dunes may display a high species diversity, there is limited endemism. Although a few species, by virtue of their really unique requirements, have managed to overcome the problems posed by the dune environment and are found nowhere else, such as the Little Portland moth (*Actebia praecox*), whose larvae feed on Sea Wormwood (*Artemisia*

maritima), and the Creeping Willow (*Salix repens*; DOWDESWELL, 1984).

One of the most important factors determining the composition and distribution of the dune fauna is the structure of the vegetation and the associated microclimates (McLACHLAN, 1991). Increasing vegetation cover, often coupled to succession, mediates physical stress, creates stable microenvironments and is responsible for a general increase in habitat complexity landwards. The changes that occur along this gradient from the beach to the land (FIG 9) include several faunal responses:

Crustaceans of marine origin decrease in abundance landwards. Many of the special adaptations, which equip fauna for psammophilic lifestyles and allow them to cope with salt-spray and temperature extremes, are only encountered near the beach.

Insects, vertebrates and interstitial fauna increase in abundance landwards, as vegetation cover, height and diversity increase, soil develops, pH drops and greater stability is attained. Biological interactions and impacts of fauna on vegetation via grazing, seed disposal and disturbance also increase landwards. Birds may replace small mammals such as rodents as the vegetation height increases, from low ground cover to trees, and there may be a shift from primary r-strategist species near the beach which make use of the unstable habitats there, to K-strategist species inland, where in the more stable and vegetated parts of the dunes, there is a greater need to develop competitive ability and where the need to avoid predators is more imperative. Therefore the turnover rates are fast-growing and decrease to wards the forest end of the gradient, where much energy is tied up in relatively inert woody biomass (McLACHLAN, 1991).

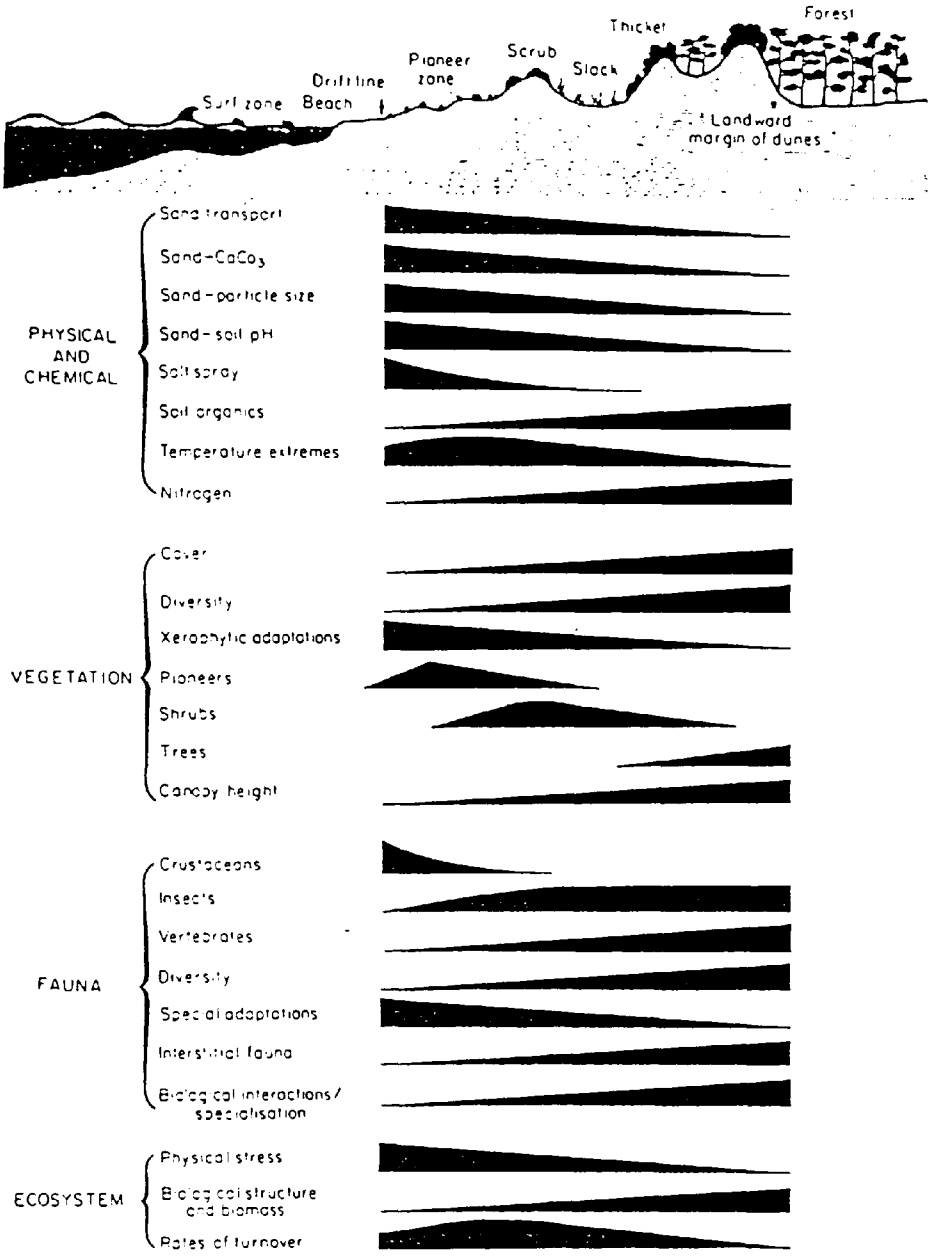


Fig 9 conceptual model of physical, chemical and biological gradients across a coastal dune field in a non - arid region (McLACHLAN, 1991).

CHAPTER 4

HUMAN USE AND IMPACT ON COASTAL SAND DUNES.

"It would seem that all dune systems in Britain have a legacy of historical human influence" (HOUSTON, 1992 p25). They have been grazed, afforested and cultivated. They have also been useful sources of aggregate, and of ground water; provided sites for aerodromes, railways and roads, domestic housing and industry. In the past, they have been in much demand for sites of military training. They also form a bulk defence in coastal protection, and because of their sandy shores they are of outstanding value to recreation.

4.1 Grazing.

4.1.1 Stock Grazing.

Both sheep and cattle are grazed on dunes, and it would seem that areas with a long history of stock grazing, are often very species rich (BOORMAN, 1977). But because of the foot pressure exerted by these large animals the dune sward tends to become damaged, which results in the consequent risk of erosion. A cow's hoof exerts a pressure of 7-10 kg cm^{-2} and a cow treads one ha of pasture some 8-9 times a year. The hoof of a sheep however, exerts 4-6 kg cm^{-2} pressure, but a sheep treads one ha of pasture 20 times a year. Therefore sheep exert 25 - 45% more total impact per unit area than cows (RANWELL and BOAR, 1986).

Sheep also graze more closely than cattle and reduce the sand trapping capacity of dune turf. They also range more widely over the uneven topography of the dune system, and cause erosion on paths and lairs associated with steeper slopes. Grazing also tends to reduce rooting depths, which are critical in mid-summer drought conditions. Further, part of the productivity cropped by the stock is lost to the system when the animals are penned, representing a loss of organic matter, which would otherwise contribute to stability in the form of soil humus (RANWELL and BOAR, 1986), although grazing intensities of 0.5 cattle per ha yr^{-1} and 4 sheep per ha yr^{-1} can be supported by dune turf.

In Britain there has been a decrease in the utilization of these relatively marginal grazing areas as part of a general movement away from extensive stock farming, probably as a result of increased labour costs making the supervision of low-return grazing uneconomic (BOORMAN, 1978).

4.1.2 Rabbit Grazing.

In Medieval times the rabbit was deliberately cultivated in English and Welsh dune systems, but control was difficult and wild populations soon became established (RANWELL, 1972). The impact of rabbits is quite considerable, due to both their burrowing and grazing activities. Rabbit burrows can become focal points for the occurrence of blowouts, as their holes become rapidly enlarged by wind erosion. But whether or not this will occur will depend on the overall degree of stability within the system and the extent of the area affected

by the rabbits (BOORMAN, 1977). Another effect of their burrowing is that conditions for pioneer stages of vegetation succession are maintained and development into shrub structures is retarded and sometimes even locally controlled (OOSTENELD, 1985). Their burrowing also results in the reworking of the dune soil.

The impact of rabbits on the vegetation depends very much on the density of the rabbit population, and the spatial distribution of their burrows (BOORMAN, 1977). Grazing tends to be restricted to areas around active burrows, and over wide ranges of rabbit population densities there is a mosaic of areas with different grazing densities. At low densities rabbits help to maintain species diversity by actively selecting against shrubs and grasses, which creates more open communities for dune annuals intolerant of competition from perennial species near the burrows. As the density of the rabbit population increases, increased grazing pressure produces a close sward of annual and perennial species, combined with mosses and lichens, this sward often only being 2cm in height. Between this stage and the next, (which is represented by a breaking up of the sward with increasing areas of bare sand) there is a very delicate line, and once this line has been crossed and turf has been destroyed, recovery can be very slow (BOORMAN, 1977).

Undergrazing, however, can also bring its problems. With the advent of myxomatosis in the 1950's there was a considerable decline in the number of rabbits to be found on British dune systems. This resulted in large areas of closely cropped dune turf being replaced by tall, rank grassland with scattered shrubs, such as occurred at Newborough Warren, Anglesey (HODGKIN, 1984). It is this uncontrolled shrub development that is the problem, as it actually shades out the dune turf species and results in an increased fire risk. Rabbit

numbers, however, have since recovered to such an extent that over-grazing is again a problem on a number of dune systems.

4.2 Afforestation.

Woodland is the natural vegetational climax for many dune areas, but the deliberate planting of tree species, particularly conifers has occurred extensively in England and Wales, with several of the largest dune systems becoming, in the very least, partly afforested, for example; Pembrey (Carmarthen), Newborough (Anglesy), and Whiteford (Glamorgan).

The initial planting of the tree species, *Pinus sylvestris, P. nigra* and *P. pinaster*, was done with the aim of dune stabilization in mind. These coastal fringe woodlands create effective shelter belts (reducing the windstrength for distances of up to 25 times their height), for commercially viable conifer plantations further inland (BOORMAN, 1978).

Although afforestation can result in a large influx of introduced species to a dune system, the deep shade of the mature plantation virtually eliminates the natural ground flora. Ovington (1951), also showed that in afforested parts of Tentsmuir, Fife, the water-table was some 27cm lower than in comparable unplanted areas, reflecting the high water abstraction power of the pine trees. In addition, to improve the growth of the pines at Fife, drainage ditches were cut to reduce waterlogging, and this further reduced the level of the water-table for quite a large area around.

Following afforestation, there does tend to be an increase in the soil organic content, enhancing the water holding capacity of the soil, but there also tends to be a decrease in the soil nutrient level and an increase in the soil acidity. Also once established, *Pinus* species seed and regenerate freely, resulting in a considerable natural spread outside the area of afforestation (BOORMAN, 1977).

4.3 Sand and Gravel Extraction.

Dune systems are a useful source of aggregate for building purposes, as was the case at Merthyr Mawr (Mid Glamorgan), where the sharp sand was in much demand for plaster and concrete (GILLHAM, 1987).

In most parts of Britain, these onshore mining activities are now of comparatively minor significance, following awareness of the sensitivity of dune landscapes to erosion (RANWELL and BOAR, 1986). Removal of sand from the coastal dune creates a continuously eroding seaward face and destroys dune grasses vital for dune regeneration. Removal from back dunes may mobilize them and result in the overwhelming of adjacent property by sand inundation. Lowering of the dune level by sand or gravel extraction may, depending on local topography enlarge the consequences of a chance breach in the coast dune, as happened at Merthyr Mawr (Mid Glamorgan), where from 1937-1973 sand and gravel was commercially extracted from the frontal dune system, which consequently resulted in a sea breach being formed (GILLHAM, 1987).

However local needs for building materials in remote sites may necessitate some sand extraction from "safe" landward sites.

4.4 Industrial and Residential.

Housing and permanent-standing caravans on dune systems, bring with them a year-round impact from people to the dune system, so that it may have little chance to recover from one season's damage to the next. Such development may also increase the risk of undesirable plants being introduced to the system, from garden rubbish, and there is also an increased risk of fire (RANWELL and BOAR, 1986). Also sewage works, like the one built in 1972, at Merthyr Mawr (Mid Glamorgan), and service pipes (eg of sewage effluent), may need to be laid through a dune system, in association with housing development. However, since the trench-lines are narrow, and usually follow low elevation routes, they can be readily stabilized by planting after refill.

4.5 Water Extraction.

Excessive ground water extraction for domestic housing or industrial use in the locality of a coastal dune system has three adverse effects.

a) It can destroy the wetland vegetation, because the rate and magnitude of changes in the

water level are so great that the natural plant communities are unable to compensate (BOORMAN, 1978).

b) The existing water table is lowered, and thus wind erosion can lower the dune surface further.

c) It can also result, in saline incursions into the groundwater, such as occurred at Southwold (Suffolk). This salt penetration, will at the very least, temporarily damage the dune slack vegetation, as the vegetation landward of the coast dune is dependant on fresh water (RANWELL and BOAR, 1986).

4.6 Military Use.

During World War II a number of dune systems were used as training areas, such as at Oxwich (West Glam), Ynyslas (Dyfed) and Prestatyn (Gwynedd). This invasion proved to be highly destructive: Sand was mined to produce concrete anti-tank and block-house constructions; tracks were bulldozed to open up access to the shore or remote parts of the system; all terrain vehicles were introduced; and missiles were exploded. Most of the damage has now been repaired, despite problems caused by unexploded objects buried in the sand. Present military use of dunes is largely limited to relatively environmentally harmless installations, such as the military establishments on Pendine and Laugharne dunes(Dyfed).

4.7 Transport.

A number of dune systems in the British Isles have been levelled for aerodromes, such as Valley (Anglesey), and part of the dune system at Morfa Dinlle (Gwynedd). Although while in use, these installations restrict public access, once disused however, the abandoned roads and runways encourage public access at abandoned sites which will result in localized pressure on adjacent vegetation.

4.8 Recreational use.

Sand dunes form a very attractive natural target for recreation. This coupled with the fact that the very nature of the coast as a fine weather destination, means that there will inevitably be times when very large numbers of visitors will arrive on a single day. For example, the average number of visitors at Formby Point (Merseyside) on a summer's Sunday is in the region of 3,700 people (WHEELER *et al*, 1991).

The main recreational activities on coastal dunes in order of diminishing impact on dune vegetation are: The driving of off- road vehicles, horse riding, walking and golfing (RANWELL and BOAR, 1986; WILLIAMS and SOTHERN, 1986; WILLIAMS and RANDERSON, 1989). These activities will either directly or indirectly, affect the dune system. The level of effect will be a consequence of the sites geology, soil type, slope, aspect, species composition, the past management regime and the weather conditions at the

time of use (BURDEN and RANDERSON, 1972).

4.8.1 Off - Road Vehicles.

Off-road vehicles (O.R.V) have a substantial effect on dune vegetation, which can eventually lead to the systems degradation. The most sensitive areas in a dune system to off -road vehicles are:

a) Drift lines and embryonic dune areas;

b) The leading edge of expanding dunes;

c) Older, stable dune areas where drivers would be inclined to leave tracks;

d) Heathlands and lichen communities (LEATHERMAN and GODFREY, 1979).

O.R.V tyres effectively reduce the height and density of the dune vegetation, and increase soil compaction, which in turn reduces the amount of oxygen available for respiration around plants roots (RANWELL and BOAR, 1986). Experimental data (LEATHERMAN and GODFREY, 1979) seems to indicate that it is in fact the first few passes of a vehicle across the dune vegetation that are the most critical and damaging. It was also found that no one species had a greater capacity to withstand O.R.V impacts than another.

Liddle and Greig-Smith (1975) measured the influence of tyre wear on dune turf at

Aberffraw (Anglesey). They found that the passage of 200 vehicles in the summer reduced the dune grassland plant cover by 50%. They also found that the bulk density and soil penetration resistance was related linearly to the log of the number of car passes up to 256 passages. These physical changes and the loss of plant cover will lead to dune instability and promise dune migration. Additionally, because of vehicular passage the re-establishment of the plant communities will be prevented. These bare areas will thus remain open to wind erosion, which will eventually lead to blowout development.

The physical forces applied to the sand by ascending or descending wheels, result in a downward transportation of sand. On an 8 degree slope some 2000cm^3 of sand would be transported by a single vehicle approaching perpendicularly to the slope, falling to less then 1000cm^3 when the approach is near parallel to the slope. Thus over a period of time the dune profile can be significantly lowered (by as much as 0.6m annually), in those areas frequented by vehicle use (LEATHERMAN and GODFREY, 1979).

Recovery of the dune vegetation occurs at different rates and is dependant on the particular species, lifeform and the environmental conditions present (HYGAARD, 1980). The most stable sites, and those with natural stresses such as drought and low nutrient levels, take the longest time to recover, whereas the more dynamic sites, with inputs of new sand, nutrients and moisture tend to recover more rapidly. Thus recovery of vegetation on the foredune area may take at least 4 years, but recovery in the backdune area will be more protracted, perhaps taking more than 8 years to recover (LEATHERMAN and GODFREY, 1979).

4.8.2 Horse - Riding.

Horse-riding is a popular recreational pursuit, but its environmental impact is quite considerable (BOORMAN, 1978; WILLIAMS and RANDERSON,1989). Physical damage to the soil and the vegetation is caused by horse hoof impact, being most destructive when the horse is trotting as the weight is distributed over the minimum hoof area with close to maximum frequency of hoof impact (RANWELL and BOAR, 1986). Also as large numbers of horses tend to follow more or less the same track, the dune sward will eventually be completely destroyed.

4.8.3 Human Trampling.

At the present time human trampling is the most widespread human impact on dune vegetation in England and Wales. All unfenced parts of the dune system not covered by impenetrable scrub is freely accessible to the public, with high dunes attracting attention as viewpoints (RANWELL and BOAR, 1986). In many cases trampling occurs due to the juxtaposition of the dunes, between a car park or an access point to the beach (BOORMAN, 1978). Sothern (1987) investigating human trampling on dune vegetation at Merthyr Mawr (Mid Glamorgan) showed that indeed, there was a concentration of impact within a 250m semi-circle of the car park and along the 1.5km line between the car park and the beach, an area of great dune mobility. However, an increasing number of people are seeking to explore Merthyr Mawr, and effects of their feet on the vegetation is becoming an

increasing problem. Boorman (1976) found that 10 human trampling passes per month reduced dune turf height by 66% at Winterton (Norfolk), and 40 passes per month reduced the turf height by more than 75%. It was also estimated that bare ground would appear when the trampling level approached 80 passes per month, and that 150 passes per year would produce 50% bare ground. Most damage to the vegetation by walking occurs from compaction by the heel in the early part of the step and then shearing by the toe action at the end of each step. Both actions will have direct mechanical effects on the vegetation, but it also affects the vegetation indirectly, affecting plant growth and species diversity through the result of soil changes (see chap 3.3.2; LIDDLE and GREIG-SMITH, 1975).

The extent of this problem can be seen from the work of Van der Werf (1970). He estimated that in the Meijendel (near The Hague), a dune valley system of 104ha, some 33ha had lost their natural character completely (7ha being made up of roads and tracks, parking places 2ha, paths 6ha and very heavily trampled areas 18ha), 47ha were moderately to strongly affected, leaving only 24ha more or less unaffected, despite the fact that this area had active management towards dune protection and conservation.

The problem is further aggravated by the fact that once the sward has been destroyed, revegetation will be inhibited by even light trampling (BOORMAN, 1978).

4.8.4 Golf Courses.

The recreational use of coastal dunes as golf courses restricts the public access to a level

which does not damage the vegetation (RANWELL and BOAR, 1986). However, the greens themselves are intensively managed and species poor (BOORMAM, 1978). Also the modern techniques of "improving" the greens with fertilizers and irrigation, such as has occured at Morfa Bychan (Gwynedd), destroy the original dune sward and produce vegetation vulnerable to salt water incursion and exceptional drought (RANWELL and BOAR, 1986). The rough areas however, that are intermittently mown support a relatively rich flora. This was illustrated by Ranwell (1975) in a study that was carried out on the flora of a Jersey golf course. It showed that the intensively managed fairways had 5 -10 species per $25m^{-2}$ compared with 30-40 species per $25m^{-2}$ in the undisturbed (unmanaged) areas.

CHAPTER 5

DUNE MANAGEMENT

'To manage' means to direct or to control (OXFORD DICTIONARY, 1994). Conservation Management means interference, either to produce desired changes or to prevent others which may be undesirable. 'Conservation Management' however, can mean as many things to people as does conservation itself. The British Trust of Conservation Volunteers (1979) has drawn up a number of possible aims that should be considered in order for the land manager to evaluate their own views. Such aims include:-

a)Limitation of human impact in a natural area. For example, by fencing off sensitive areas as occurs at Oxwich NNR (West Glam).

b)Maintenance of geomorphological interest. This is of primary importance on many coastal nature reserves, eg Ynyslas (Dyfed).

c)Management of ecological succession in order to preserve or increase a sites scientific interest. In this case management may accelerate, maintain or retard the rate of succession depending on the perceived effects of succession on wildlife. This can be illustrated by the work carried out at Kenfig NNR (Mid Glam), where the selected slacks are being 'scraped' to retard the rate of succession.

d)To save species endangered on a local, national or global level, by providing for their

habitat requirements, or further by creating sanctuaries for their protection, eg Fen Orchid (*Liparis loeselii*) at Kenfig NNR (Mid Glam).

e)Creation, protection or maintenance of 'unofficial nature reserves' to act as supply areas for official reserves, without which the latter may lose certain species which cannot be maintained by the official reserves alone.

f)Serving people, usually by protecting a resource 'for the use of the most people for the longest period of time'. Amenity, recreation and resource utilisation may be accepted as legitimate in this view, although each use may be valued differently by different interests.

Land managers must seek to reconcile the demands of recreation and amenity with those of nature conservation. The goal is to combine these uses in a balance which is appropriate to the individual site. Once preliminary analysis and site surveys have been made, management requirements need to be clarified by answering the following questions.

1)Is there a need for direct habitat management? This usually means, control of ecological succession and diversification of existing habitats. Which plant species are dominant? Should they be controlled? Or is additional planting needed? If so, which species would best adapt to the site without becoming too invasive?

2)Is there a need to manage human uses of the site? What can be done to counteract damaging developments in the vicinity? What is the carrying capacity for desired uses?

Human misuse of coastal habitats almost always provides the main cause of their

deterioration. Access facilities should be planned as carefully as possible before their installation, since damage afterwards may be hard to correct.

3)Does the area surrounding the site need to be managed as well? Many threats to coastal habitats come from industrial, recreational, agricultural, or housing developments outside the immediate vicinity. A site may lose much of its wildlife interest if surrounding land is improperly developed.

4)Is management needed to protect existing site uses or surrounding developments, which cannot themselves readily be changed? Even where dune erosion, for example is naturally caused it may be necessary to stabilise the dunes to protect housing or roads. This interference should however only be considered as a last resort.

5)Does the site have management priority over others? Does it really need interference or can it go its own way for some time without losing value? Given the limited resources available for any management work, are there other sites more in need of immediate attention?

6)Can less be attempted than is tempting? The sensitivity of some habitats to interference means that there may be a danger of trying too much too soon, with unexpected and unwanted repercussions. It is advised that management work should be phased, if possible, so that it can be checked early before making a commitment to the entire programme and so that unavoidable damage may be localised and minimised. If a programme requires completion in order to be successful it should be started only when there is certainty of

carrying it through.

7)How long will improvements due to the works remain? Will they wear off and conditions be the same or possibly worse as a result? Put another way, will the site require continued surveillance and management? If so, this must be included as part of the work programme.

If management work is judged necessary, each available work method should be evaluated by asking if it will:-

a)Achieve the desired results.

b)Minimise disturbance to wildlife due to habitat destruction.

c)Minimise disturbance to wildlife due to interference at crucial times, ie flowering or nesting seasons.

d)Involve risk to humans, non-target wildlife or agricultural crops or livestock.

e)Risk damage to equipment or physical installations on site.

f)Risk damage to other peoples property.

g)Require legal permission from government authorities or landowners.

h)Be possible given available labour.

i)Be possible given available funds for capital and operating costs.

j)Be possible given site topography and problems of access.

In the dune environment, management is seldom once-and-for-all. Areas must be fenced and planted in rotation, paths must be realigned and duck-boards lifted and so on. Most frequently, the techniques which require a continuing but low-level management input, are chosen rather than attempting more permanent but expensive and inflexible measures (COASTLANDS, 1979).

The North Berwick Study Group, highlighted a number of precepts that should be adopted by all bodies concerned with dune management. One conclusion was that the correct methods for protecting and restoring dunes can only come from a full appreciation of the forces of sea, wind and human use, and the resources available (ANON, 1970).

An effective management strategy would depend upon this essential information being objectively measured if possible, rather than assumed, since the quality of decision making will suffer if the data on the systems controlling parameters is not systematically collected and analysed. A checklist approach to data collection as presented in this thesis will give an orderly and systematic approach to data collection which can be incorporated into the process of 'Strategic Decision Making and Dune management'. Strategic management is one that has a clearly identified policy and plan of action targeted to achieve specific objectives. The

related decision making should be rational, involving an objective assessment of the evidence and a logical choice of actions. "However, rationality is not a factor that can be taken for granted, with problems of information, goal diversity and psychology leading to non-rational decisions. It should be noted that whilst rational techniques are available to assist choices they cannot make those choices because of the presence of qualitative variables within the environment. Indeed there are dangers inherent in trying to make the analysis too rational since the approach could become inflexible, formalised and excessively quantitative"(DAVIES *et al*, 1995 p88).

A strategic approach to dune management is desirable since it is a means by which factors influencing the long term behaviour of the dune system can be identified and management responses initiated. Mintzberg and Waters (1989), have described a number of strategic planning types eg:-

i) 'Deliberate':- This requires an environment that is perfectly predicable, benign and under full control of the manager.

ii) 'Imposed':- This is an appropriate response to changes of environmental parameters where the system is largely understood and predictable.

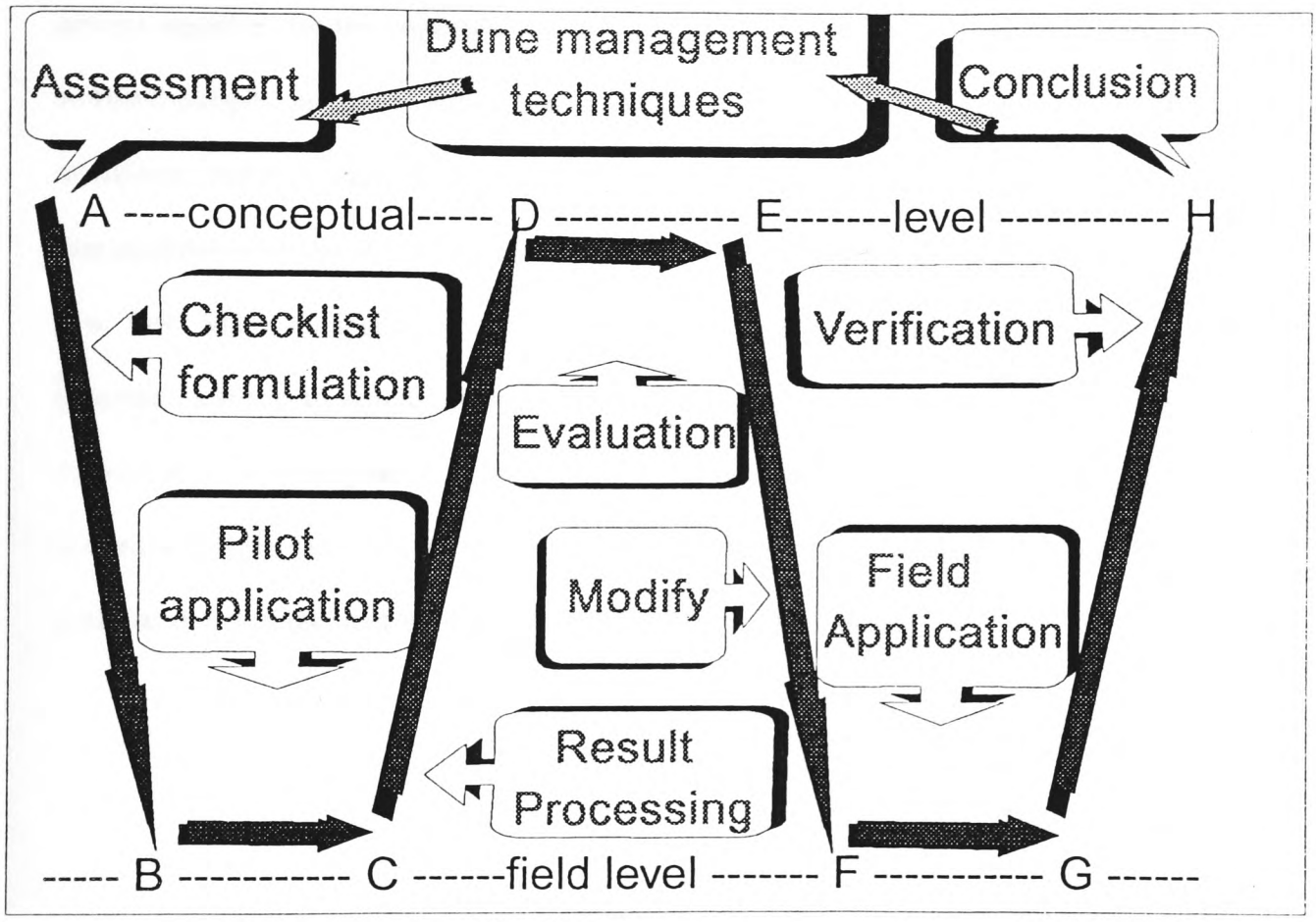
iii) 'Umbrella':- This is applicable where elements of the environment are uncontrollable and unpredictable. Only general guidelines for behaviour can be set in such contexts. ie, overall boundaries are defined within which some parameters can be manoeuvred. This strategy requires the maintenance of a delicate balance between proaction and reaction.

iv) 'Emergent':- This is appropriate where the environment is too unstable or complex to comprehend. Such systems require open, flexible and responsive

management styles.

Taylor's (1961), nine step eclectic PakSA problem solving technique identifies the need to "get", "organise" and "refine" knowledge. The emphasis is not on ideas, but the gathering of information which is reliable, sufficient, impartial, consistent, comprehensive and of predictable value, with the data being organised into a logical format, particularly where the problems are complex. As previously stated in the environmental monitoring and knowledge gathering contexts checklists are a useful approach. Davies *et al* (1995), have put forward a checklist methodology, whereby management problems can be identified and solved. The checklist enables spatial and temporal comparisons to be undertaken, and discontinuities detected. This is an important management requirement since environments do not necessarily change on a regular or orderly basis. Non-linear variations are possible and monitoring through repeated application of the checklist should identify these changes, whereas major shifts in the environment will be immediately apparent and cause rapid strategic responses, eg. foredune destruction in a major storm. Identification of subtle changes which could undermine the long term survival of the system are however, a more significant management challenge. This methodolgy is particularly successful if it is incorporated into a W problem solving model. The W model is an iterative process which involves successive phases of conceptual thinking, field testing, evaluation and modification to achieve a final verified approach (FIG 10). The name is derived from the visual (W) associated with this sequence of problem solving (DAVIES *et al*, 1995). It s a useful methodology for systematising information and problem solving which sprang from the KJ method for structuring anthropological field data (OPEN UNIVERSITY, 1994). It is imperative that dune managers are aware of

FIG 10 : The W Model of Problem Solving



existing parameters and patterns so that emerging discontinuities can be recognised where necessary, and if necessary encouraged. Most past researchers have regarded dunes as vulnerable because of their propensity to show dramatic change under stress. Vulnerability can be defined as conditions causing accelerated erosion, ecosystem decay and an advanced state of degeneration with obliteration of the dune surface. However such changes are not always negative, for the importance of bare sand is increasingly being understood as essential to resist atrophy in coastal dunes. If this state is not developed by natural events it can be artificially induced, such as in Oxwich (West Glam) and Kenfig (Mid Glam). The level of management will usually determine the degree of 'conditional vulnerability'. In most cases it is 'low' where management polices are effective, and 'high' where no management policy presides, leading to extensive degradation. However, where the degree of utilisation is minor, a 'non-management' policy may be a rational response. Similarly, a positive sediment budget can mitigate the losses induced by human or animal influences so that the scale of the management intervention required may be limited.

CHAPTER 6

METHODOLOGY

The use of a checklist approach is common in many scientific disciplines, having been used in several types of studies, for example, river and beach aesthetic assessments by Leopold (1969) and Williams *et al* (1993), as well as rubbish and fly tipping investigations by Williams *et al* (1993). However until recently few have dealt with the context of dune management. One approach was being developed by Partridge *et al* (1994), where they were attempting to use dune vegetation as an indication of dune erosion vulnerability. Difficulties have been encountered in this approach by conflicting advice from dune ecologists, so much so that it seems from recent reports (WILLIAMS pers comm) that the project has been shelved. Although generalisations can be made it is questionable whether you can treat plants in the same manner as physical structures since they can have complicated autecology, good and bad years, be affected by climate and have plant/soil, plant/water relations etc... (HOUSTON pers. comm.).

A number of pilot studies were carried out (Williams *et al*, 1993) to develop a checklist to quantitively assess the vulnerability of a dune system and the effectiveness of protection measures. It is this honed procedure that is being used in this thesis to assess the major ($>$50ha) dune systems of Wales (DOODY 1991).

The checklist procedure used is founded on a belief in the value of a structured approach to

assessment of dune system conditions, spatially and temporally (DAVIES *et al*, 1993). It can be relatively easily applied by both specialists, non specialists and managers from a variety of discipline backgrounds.

Information from topographic, geological maps, photographs, and most importantly field investigations is entered onto the checklist proforma. The condition of the system is assessed by a series of 54 parameters which are organised into five sections:-

Section A :- Site and Dune Morphology (8 parameters).

Section B :- Condition of the Beach (9 parameters).

Section C :- Character of the Seaward 200 meters of Dune system (12 Parameters)

Section D :- Pressure of Use (14 parameters).

Section E :- Recent Protection Measures (11 parameters).

The investigator proceeds through the checklist, using the rating scale, usually 0-4 for each parameter (TABLE 1).

Summation of the first 43 parameters (section A-D) give the site vulnerability index (VI%). The remaining 11 parameters provide an index of the recent protection measures undertaken at the system (PM%).

The data can then be presented numerically by the VI/PM ratio, as well as diagrammatically (TABLE 3 & FIGS 11-22). Using this information the dune systems can then be divided into 3 sub groups depending on the management status at each site ie..

1)Systems Out of Management Equilibrium.

This can either be:-

a)Negative, ie a VI/PM ratio of >1.3, here the situation is that of a low management balanced against high dune vulnerability.

b)Positive, ie a VI/PM ratio of <0.8, here the situation is that of high management balanced against low dune vulnerability.

2)Systems In Management Equilibrium.

ie a VI/PM ratio of 0.8-1.3.

Here the management undertaken at the site balances with the overall vulnerability of the system.

These indices allow dune managers to assess changes in a particular site through time or to comparison between dune sites on a regional scale.

The sites selected for this investigation were the 27 major dune systems (>50 hectares; DOODY, 1991) along the entire coastline of Wales. The managers at each site were contacted with a view to the completion of a checklist for the site, under their protection. This approach however was only successful for 13 of the 27 sites under investigation. It became necessary for me to visit the remaining sites to complete a checklist. In order to assist the analysis of the incomming results I visited every site, to obtain a general "feel" for the area being investigated. However I was not able to visit the dunes at Newbrough Warren (Angelsey), and Prestatyn (Clwyd), due to restricted time and resources.

CHAPTER 7

RESULTS AND DISCUSSION.

The following discussion is based on a sample of the 27 dune sites investigated along the coastline of Wales. The sites have been divided into 3 sub-groups, depending on their management status. For each sub-group 3 sites have been selected to illustrate the management requirements of the whole group.

1)SYSTEMS OUT OF MANAGEMENT EQUILIBRIUM.

a)NEGATIVE. ie VI/PM ratio >1.3 (TABLE 3, FIGS 11,12,15 & 16).

LOW MANAGEMENT : HIGH DUNE VULNERABILITY.

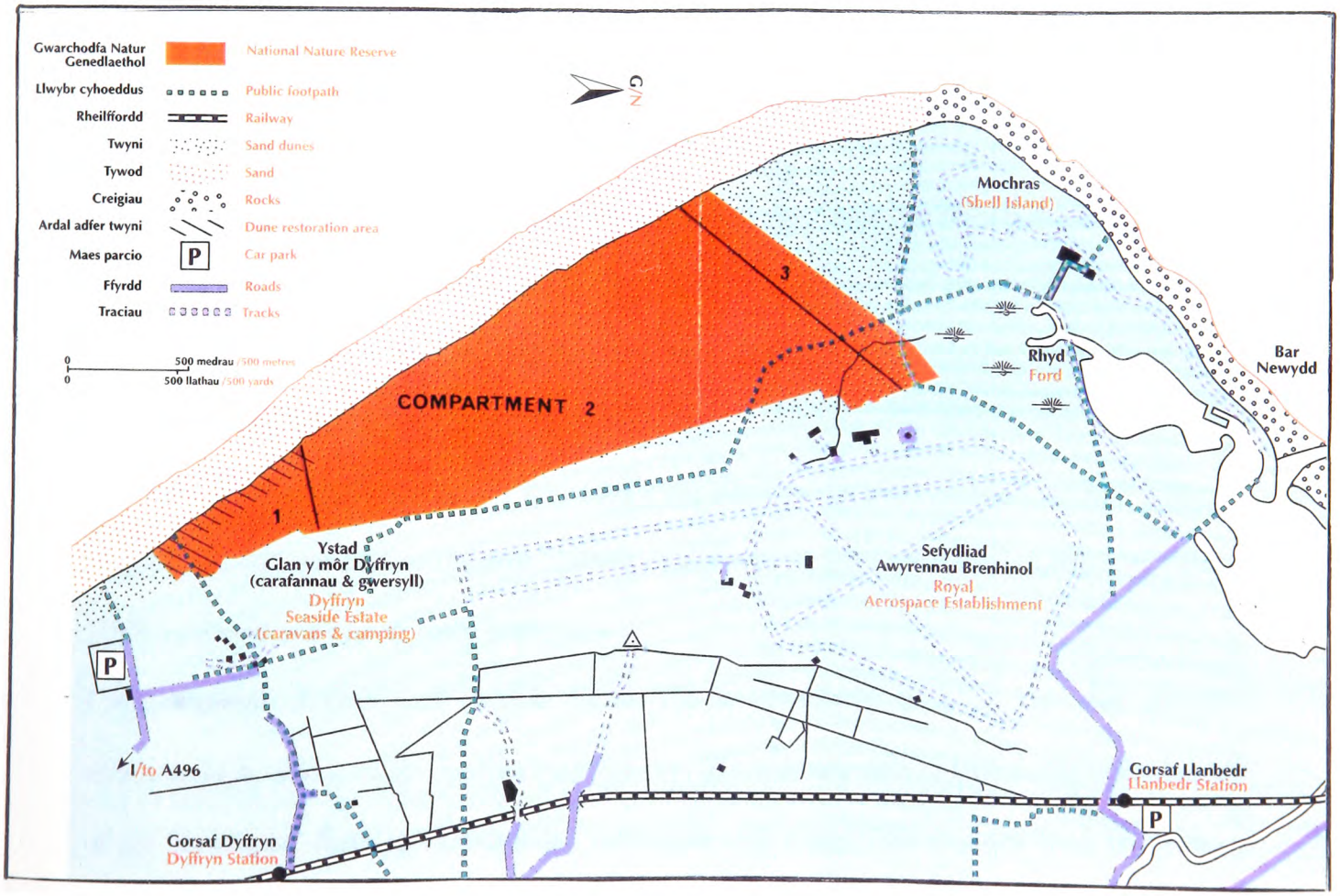
i)**Morfa Dyffryn.** (VI/PM ratio 1.59)

The dunes of Morfa Dyffryn are situated within the Snowdonia National Park, at grid reference SH553264-SH576218, and cover an area of 313ha. They extend from the mouth of the Afron Ysgethyn northwards to Mochras, being roughly triangular in shape. It narrows to a single line of fragmented dunes in the south becoming broader towards the north. At the northern edge of the system the single dune ridge splits, and two diverging major dune ridges form the seaward and landward boundaries of the dune system. The area in between is mainly dune slack, but the whole area is complicated by extensive mobile dunes.

Glaciation was a major factor in the development of the system. During the last iceage

PLATE 1

MORFA DYFFRYN



the north-east part of Cardigan Bay was protected from the southward advance of the Irish sea ice by the Lleyn Peninsula. The ice from Snowdonia and the Meirionnydd ice cap was trapped by the massive bulk of the Irish sea ice and stagnated. Sediments deposited from these glaciers, both directly and in melt-water lakes that were trapped by the Irish sea ice, helped create the foundation of the Morfa.

The site supports an extensive range of calcareous, sand dune habitats, despite the fact that the strandline is a noticeable absentee, and foredunes are poorly represented (MORFA DYFFRYN MANAGEMENT PLAN, 1991). The sites diversity is clearly related to habitat instability. The site is very dynamic and there is a considerable amount of seral change taking place, which is verified by the site receiving the second highest recorded value for the surface character of the seaward 200m of 75% (TABLE 3). As a result of the diversity the site possesses an interesting flora with many important sand dune communities. Three plants that are on the NCC's list of nationally scarce vascular plant species are present on the site, these being the Seaside Centaury *(Centaurium littoral)* Sharp Rush, *(Juncus acutus)* and the green-flowered helleborine *(Epipactis phyllanthes)*.

Because of the obvious ecological importance the site was declared an SSSI in 1953. Then in 1962, the greater part of the area (220ha), was declared a National Nature Reserve. The NNR is best described in three sections:-

Compartment 1: This area which forms the southernmost part of the site covers approximately 19ha, and is eroding very rapidly. Each spring-tide or storm cuts away more of the foredunes, forming an unstable, vulnerable cliff edge. The exposed sand is rapidly blown inland where the over-heavy deposition rates overwhelm the stabilising

TABLE 3 : SCORES ATTAINED FOR EACH DUNE SYSTEM IN EACH CATEGORY OF TABLE 1

DUNE SYSTEM	A%	B%	C%	D%	VI%	PM%	VI/PM
MERTHYR MAWR	50	27.8	45.8	32.1	38.4	43.2	0.88
KENFIG	34.4	75	35.4	28.6	41.3	59.1	0.69
CRYMLIN	62.5	36.1	47.9	7.1	34.9	40.9	0.85
BAGLAN	56.3	33.3	47.9	28.6	40.1	59.1	0.68
OXWICH	59.4	19.4	37.5	28.6	34.9	54.5	0.64
HILLEND	59.4	58.3	64.6	53.6	58.7	56.8	1.03
LAUGHARNE	56.3	36.1	39.6	18.6	34.5	36.4	0.95
BROUGHTON	59.4	47.2	31.3	39.3	42.4	37.8	1.33
WHITEFORD	46.9	25.0	45.8	17.9	32.6	31.8	1.02
PEMBREY	75.0	27.8	18.8	7.1	27.3	38.6	0.70
PENNARD	53.1	47.2	41.7	35.7	42.5	52.3	0.81
PENDINE	56.3	27.8	33.3	14.3	30.2	36.4	0.83
STACKPOLE/ BARAFUNDLE	56.3	38.9	52.1	17.9	38.9	29.5	1.31
BROADHAVEN	65.6	44.4	43.8	28.6	4.3	22.7	0.19
FRESHWATER WEST	62.5	44.4	54.2	46.4	51.2	34.1	1.50
BROWNSLADE	56.3	33.3	47.9	17.9	36.6	31.8	1.15
TENBY	71.8	44.4	35.4	40.1	42.5	43.2	0.98
YNYSLAS	68.8	52.8	79.2	32.1	56.4	61.4	0.92
TYWYN-ABERDOVEY	43.8	50.0	20.8	17.9	29.9	40.9	0.70
MORFA DYFFRYN	59.4	69.4	75.0	57.1	65.1	40.9	1.59
MORFA HARLECH	46.9	16.7	20.8	17.9	23.8	54.5	0.43
MORFA BYCHAN	53.1	50.0	35.4	53.6	47.1	13.6	5.20
ABERSOCH	84.4	50.0	25.0	25.0	41.3	50.0	0.82
MORFA DINLLE	56.6	57.8	45.8	25.0	42.0	38.6	1.10
NEWBOROUGH	31.3	38.9	33.3	25.0	31.4	53.6	0.58
CONWAY	68.8	63.9	33.3	25.0	43.1	68.2	0.63
PRESTATYN	53.1	38.9	45.8	42.9	44.8	50.0	0.89

vegetation. This area is also the most popular with visitors, with their presence accelerating the erosion process.

Compartment 2: This area which covers approximately 163ha, forms the main body of the reserve. It is reasonably robust, and is the least eroded section within the reserve. As in compartment 1, spring-tides and storms wash away the leading edge of the foredunes causing a significant loss over the entire length of the compartment, which has in part led to the system receiving a high value for the condition of the beach at 69.4% (TABLE 3). The inland dunes are very high, reaching to a height of 30m in several places, with steep profiles. These dunes are consequently mobile and very dynamic.

Compartment 3: This is a very narrow strip along the northern boundary of the site, covering an area of approximately 38ha. It is best described as part of the SSSI which extends for approximately 0.5km south of Mochras. The dunes in this area of the SSSI are high, very unstable and extremely mobile. This is probably a reflection of their relatively recent origin and the massive deposits of sand received from further south. The situation is further complicated by high visitor pressure.

There is little information about the past land usage of the dunes at Morfa Dyffryn. What is known is that the Morfa was subject to enclosure by an Act in 1806, when the area, which was previously common grazing, was incorporated into the Gors-y-gedol estate. Since that time it would appear that the land has been used for low level rough grazing, although the area containing the NNR has not been officially grazed since its designation. However, there is always a limited trespass by grazing stock, especially on the southern sector which

comprises compartment 1.

A railway was built in 1867, and since its completion, provision of facilities for tourists has become the main use of the land in the area (MORFA DYFFRYN MANAGEMENT PLAN, 1991). This can also be seen from the fact that the Morfa had the highest recorded pressure of use index of 57.1% (TABLE 3). Since 1945 the number of visitors visiting the site has increased. The numbers accelerated during the 1950's with the building of a caravan site at the southern end of the SSSI in 1952. With improvements in access this increase in tourist numbers continued during the 1960's. The numbers peaked in 1977/78, and have recently fallen back to levels similar to those of the early 1970's (MORFA DYFFRYN MANAGEMENT PLAN, 1991). Most visits to the reserve by the public are incidental to their use of the beach, and the public are generally unaware of the status or interest of the site. Access to the site is mainly through the area to the south of the reserve, which is owned and managed by the Snowdonia National Park Authority, or from the Mochras in the north. In general the middle and most valuable area of the NNR (compartment 2) is less disturbed then the extremes. However, beach use by nudists has begun to increase. They usually use the middle section away from the main public areas, however their concentrated use of some areas has caused some localised erosion. There has also been some illegal trespass by motor-cycles and four-wheel drive vehicles.

In general, geomorphological processes responsible for the creation and maintenance of this site have been largely unaffected by human activities. The large numbers of visitors to the site have however had a considerable effect on the areas around the entrance points (attributing to the high score of 57.1% for the Pressure of Use Index (TABLE 3)). These

areas became de-stabilised and have been subject to considerable restoration works. The areas affected are quite small in relation to the entire site, but unless this is controlled then resulting accelerated erosion could eventually affect the entire site. It has been expressed that it would be most unlikely that a limit on visitor numbers could ever be imposed in these areas (MORFA DYFFRYN MANAGEMENT PLAN, 1991). Therefore, the only option available is to limit the damage to the dunes and not the number of visitors. This is being implemented by the use of a board-walk at the main beach entrance leading through the dunes from the Dyffryn seaside campsite. In order to prevent further erosion it is essential that members of the public are kept out of the restoration area. This has been achieved by fencing either side of the footpath and along the seaward side of the dunes. Interestingly these are the only restoration works that have been carried out at the site, for erosion in other areas, where the process is considered to be natural, is tolerated. However how the on-site wardens define natural erosion, has not been documented. Despite this the conservation value in compartment 3 has been significantly reduced, and is very low in compartment 1. However, the conservation value of compartment 2, is very high. This is helped by the fact that compartments 1 and 3 protect the main part of the site by absorbing much of the visitor pressure. Also visitor numbers in compartment 2 are being effectively managed by the use of a visitor permit system. Attempts could be made to restore the conservation interest in compartments 1 and 3, but given the natural and human induced trends present at the site, this would either be impossible or prohibitively expensive. Recognising these constraints, a compromise has been accepted where compartments 1 and 3 will act as a shield for the main compartment as indicated above. This compromise is illustrated in the results obtained, which show that the protection index of 40.9% does not compensate fully for the level of the vulnerability

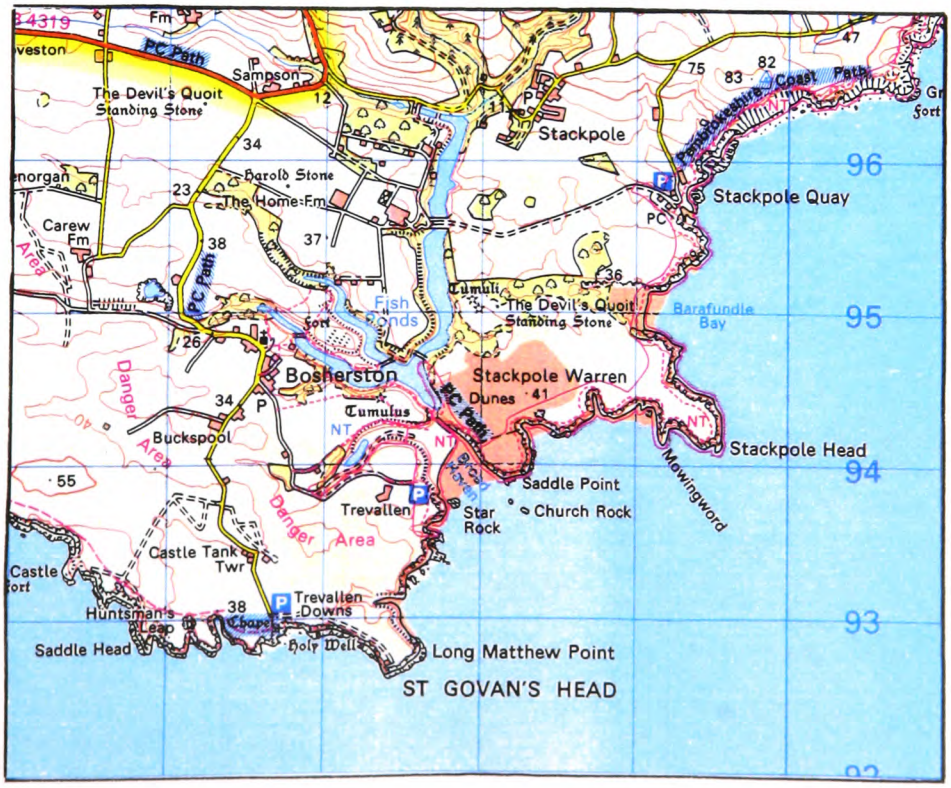
of the site at 65.1% (TABLE 3 & FIGS 11 & 12) This accounts for the loss of the conservation value for compartments 1 and 3, but as long as deterioration can be confined to these compartments, and the overall quality of the main site (compartment 2) is not impaired, then this is seen as an acceptable compromise. However this view must be balanced against the fact that the remaining 93ha of the dune system located outside the NNR, and not under NCC control, is under considerable visitor pressure. In addition and more importantly the area is not managed in a manner conducive to safe-guarding the conservation value of the site.

ii)**Stackpole.** (VI/PM ratio 1.31)

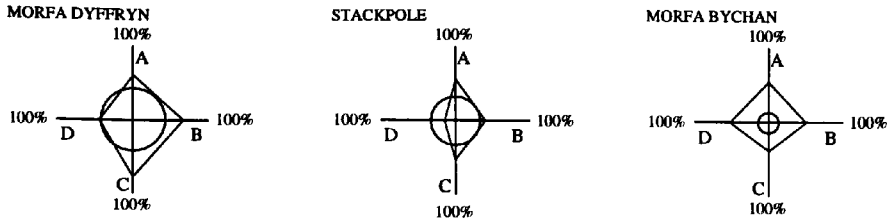
The two sheltered bay dune systems of Barafundle and Broadhaven, along with the older dune formation of Stackpole warren, perched on a classic coastal plateau surface, lie within the Stackpole NNR. The dunes form part of the Pembrokeshire Coast National Park, which was designated in 1952. The dunes are also being included within the proposed Castlemartin Coast Special Protection Area, which supports about 4% of the UK Chough breeding population (DRAFT SUMMARY PLAN; STACPOLE NNR, 1995). The dunes cover an area of 178.98ha at grid reference SR959938-SR990953, and are owned by the National Trust.

After the last Ice Age, massive deposits from the melted ice and later vagaries of climate, created the numerous sand dune areas around the Pembrokeshire coast(PEMBROKESHIRE COAST NATIONAL PARK PLAN, 1977), although photographic evidence suggests that the present dune system at Broadhaven may only have developed to its recent extent during the

PLATE 2
STACKPOLE



VULNERABILITY AND PROTECTION PLOTS FOR SELECTED SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING LOW MANAGEMENT : HIGH VULNERABILITY



KEY	
AXIS A	SITE AND DUNE MORPHOLOGY
AXIS B	CONDITION OF THE BEACH
AXIS C	SURFACE CHARACTERISTICS OF SEAWARD 200M
AXIS D	PRESSURE OF USE
CIRCLE	RECENT PROTECTION MEASURES

FIG - 11

VULNERABILITY AND PROTECTION INDICES FOR ALL SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING LOW MANAGEMENT : HIGH VULNERABILITY

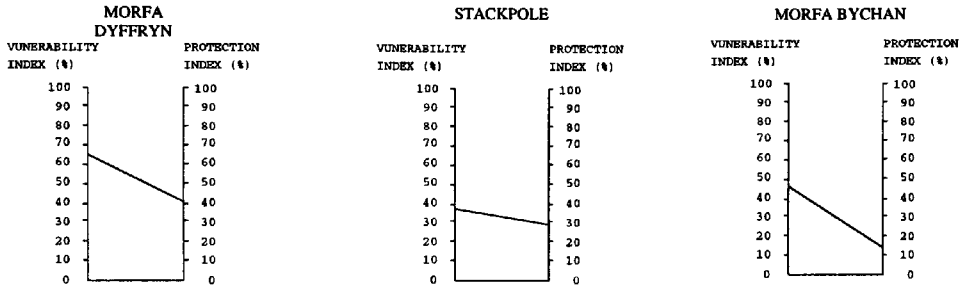
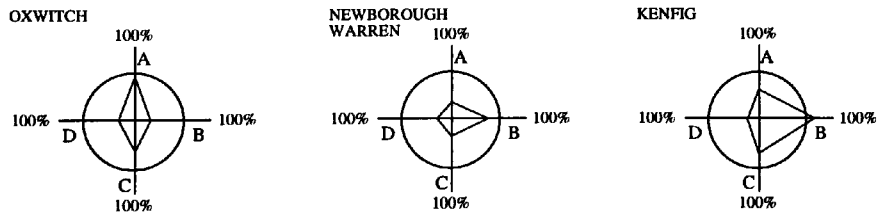


FIG - 12

VULNERABILITY AND PROTECTION PLOTS FOR SELECTED SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING HIGH MANAGEMENT : LOW VULNERABILITY



KEY	
AXIS A	SITE AND DUNE MORPHOLOGY
AXIS B	CONDITION OF THE BEACH
AXIS C	SURFACE CHARACTERISTICS OF SEAWARD 200M
AXIS D	PRESSURE OF USE
CIRCLE	RECENT PROTECTION MEASURES

FIG - 13

VULNERABILITY AND PROTECTION INDICES FOR SELECTED SITES OUT OF MANAGMENT EQUILIBRIUM EXHIBITING HIGH MANAGEMENT : LOW VULNERABILITY

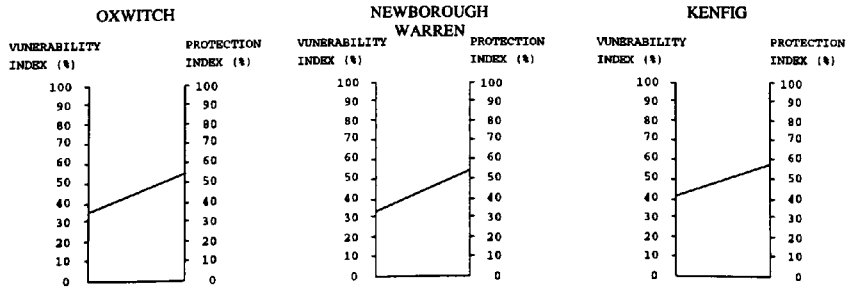


FIG - 14

REMAINING VULNERABILITY AND PROTECTION PLOTS FOR SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING LOW MANAGEMENT : HIGH VULNERABILITY

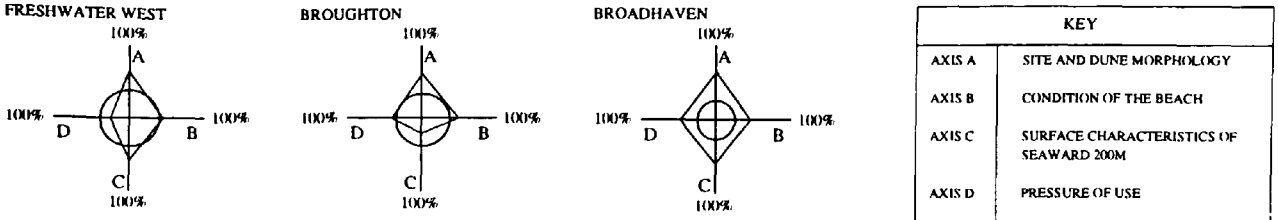


FIG - 15

REMAINING VULNERABILITY AND PROTECTION INDICS FOR SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING LOW MANAGEMENT : HIGH VULNERABILITY

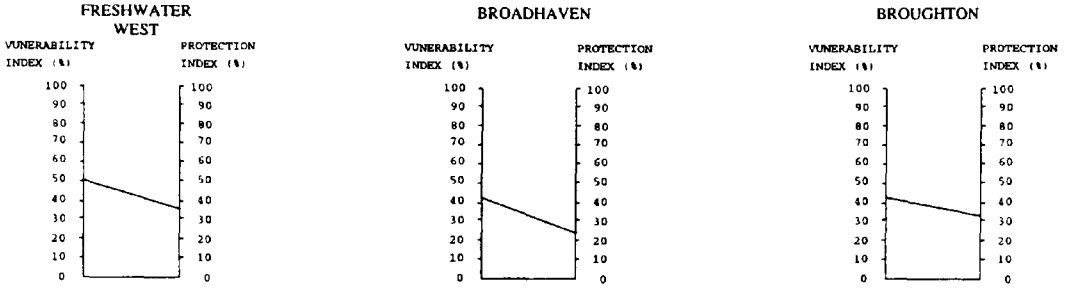


FIG - 16

REMAINING VULNERABILITY AND PROTECTION PLOTS FOR SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING HIGH MANAGEMENT : LOW VULNERABILITY

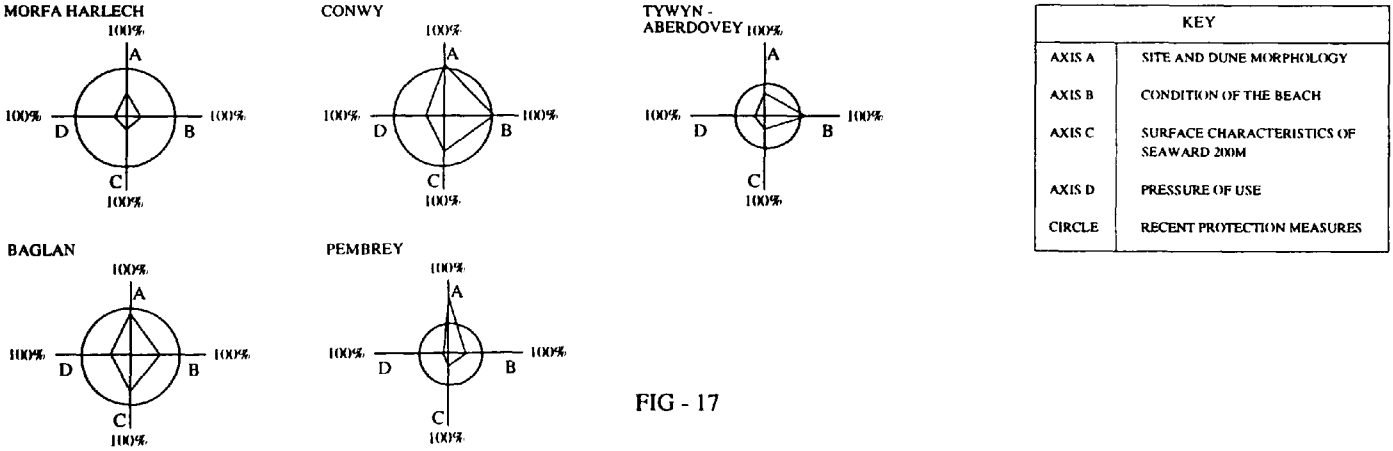


FIG - 17

REMAINING VULNERABILITY AND PROTECTION INDICES FOR SITES OUT OF MANAGEMENT EQUILIBRIUM EXHIBITING HIGH MANAGEMENT : LOW VULNERABILITY

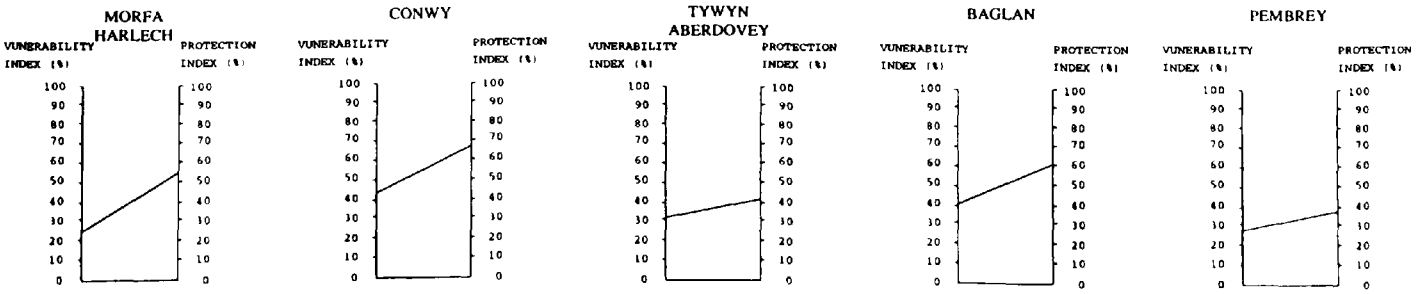


FIG - 18

last 50 or 60 years(DRAFT SUMMARY MANAGEMENT PLAN;STACKPOLE NNR,1995).

Stackpole is an exceptionally biologically diverse site incorporating a wide range of internationally and nationally important habitats and species. Terricolous lichen communities of international significance occur over the extensive dune and cliff complex. Broadhaven and Barafundle support both open and wooded dune systems, interspersed with tracts of maritime and calcareous grassland. There are also areas of calcareous heath, which are especially rich in rare lichens. The older perched dunes however, are the more interesting both physically and floristically, as they form part of a mosaic of habitat features present within a fairly compact area.

The marram dominated dunes at Broadhaven and Barafundle are now stabilised. This was helped by the introduction of sea buckthorn (*Hippohae rhamnoides*) in the 1950s and 1960's, along with the earlier planting of woodland at the sites. The much older perched plateau dunes on Stackpole Warren, were stabilised before the 1950s. The complete stabilization of the site is indicated by the relatively high score of 52.1% for the surface characteristic of the seaward 200m obtained at this site (TABLE 3).

Habitat management at Stackpole is directed at maintaining the exceptional diversity of flora and fauna by prevention of natural succession. They are using a programme of controlled grazing aided by a semi-natural rabbit population, and augmented by mowing and control of invasive bracken and scrub (DRAFT SUMMARY MANAGEMENT PLAN;STACKPOLE NNR, 1995). However there is evidence of succession occurring (from vegetation

monitoring, and photographs, including fixed point), as well as the spread of some alien introduced plant species, especially Sea buckthorn (*Hippohae rhamnoides*). In several areas this has been expanding since its introduction some 40-50 years ago. At present there is a vigorous two-pronged attack from both the National Trust, and the Pembrokeshire Coast National park wardens to eradicate this species from site (HAYCOCK, pers comm).

The balance between semi-natural erosion and over-stabilisation, must be achieved to maintain or enhance the important site features. To facilitate this the Management Plan recognises that the semi-native rabbit population must be maintained. Rabbits are limited by natural predation, disease and poaching. The health of the population is being monitored, and the authorities are attempting to prevent poaching by wardening. It has been seen that grazing by heavier domestic stock will be needed in more stable areas, to eradicate over dominance by bracken and scrub. Visitor pressure is to be monitored and access to sensitive areas such as the lichen heath communities will be prevented.

These management plans, need to be put into effect, as the results of this survey have indicated that the Stackpole NNR dunes are out of management equilibrium, having a low management level of 29.5% compared with the overall vulnerability of the site at 38.9% (TABLE 3).

The area is immensely attractive to visitors sometimes receiving up to 300,000 each year. Most people are concentrated to the 'honey pot' areas of the two safe beaches, but many walk through the area as the Pembrokeshire Coast long distance footpath, passes through the site. Despite this it would seem that Barafundle/Stackpole warren can cope with the visitor

pressure exerted upon it, under its present management regime, as it was found to have a low pressure of use index of 17.9% (TABLE 3; FIG 11 & 12). This is probably aided by the fact that this area can only be reached by foot along the cliff top from Stackpole Quay a mile away, and that the car park at Stackpole Quay is limited to 230 spaces (GOOD BEACH GUIDE, 1991). Broadhaven however has a higher pressure of use than Barafundle (TABLE 3), due to the fact that this site has a higher level of access, and that public must cross the dunes in order to gain access to the beach. As indicated by FIG 11 & 12 a greater degree of protection is needed here to prevent further degradation.

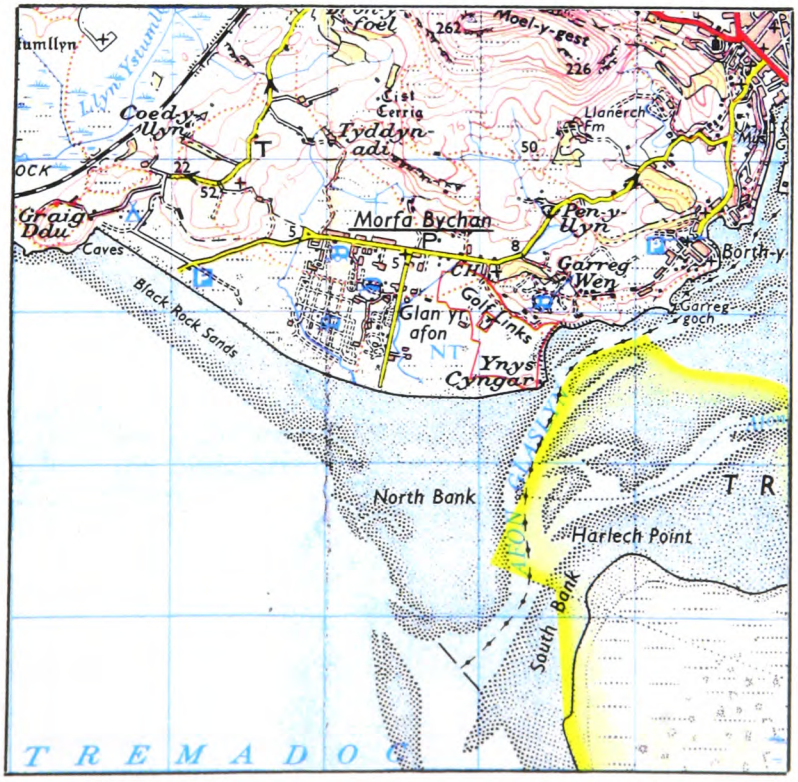
iii)**Morfa Bychan.** (VI/PM ratio 5.20)

Morfa Bychan sand dunes lie between Criccieth and Porthmadog on the Lleyn Peninsula, at grid reference SH524375-SH554369. The Dunes cover an area of 168.59ha, and were designated an SSSI in 1957. Within the SSSI lies the Morfa Bychan nature reserve, at grid reference SH54367, covering an area of 11ha. This area was acquired by the North Wales Wildlife Trust (NWWT) in 1964. The reserve was then expanded to cover an area of 17.6ha, when an additional 6.6ha was purchased in 1992.

The principal factor in the development of the dune systems around Cardigan Bay was Glaciation. Longshore drift then supplied Morfa Bychan, and other local dune systems with sand and shingle from moraines (deposited in the bay forming sand banks) and other coastal glacial deposits.

The dune system differs from most others on the West and North West coast of Wales, and

PLATE 3
MORFA BYCHAN



in fact Britain as a whole, in that it is prograding rather then eroding. Nearly all stages of dune succession and their associated communities are in evidence at Morfa Bychan, especially within the reserve, where strandline, foredune, yellow dune, semi-fixed and fixed dune grassland, slack, mire scrub and heath are found. Of these it is the fixed dune grassland community that is the largest. Although Morfa Bychan is of no great scientific interest, it does contain some rare and notable species such as the variegated horsetail *(Equisetum variegatum)* which has been recorded in the dune slacks. There is also the dune fescue (*Vulpia fasciculata)* recorded in the fixed dune grassland, and most notably the Sharp rush (*Juncus acutus)* recorded in the dune slacks at its most northerly limit on the west coast of Britain. The SSSI also includes the rare hoverflies (*Cheilosia mutabilis* and *Eumerus sabulonun)* along with the local endemic butterfly, the grayling (*Hipparchia semele)* (GARLAND, 1993).

Unfortunately there is no information available about the site on any subject area before the late 1950s (GARLAND, 1993). It is known that the grassland areas have long been grazed, 6 acres of the dunes were reported to have been reseeded several years or so before 1966. Also part of the flat grassland area was once used for sowing potatoes (GARLAND, 1993). Although growing of potatoes is no longer carried out on the dunes, the practice of cattle grazing is carried on. This activity is however, limited to the reserve area, where they are used to maintain a species rich sward over most of the fixed dunes grassland, but not as yet on the newly acquired land. The grazing is carried out under licence, which covers a period of 7.5 months, from the 15th August to the 31st of March each year. Tenancy termination at the end of March each year ensures that the stock is removed before the start of the spring flowering period. In order to prevent an excess of trampling and erosion the NWWT has

set what it feels is a relatively low stocking density on the reserve of approximately 1.77 cattle/ha. Recent work suggests, that a stocking density of 1 cow per hectare in an area of fixed dune grassland is excessive where the primary objective is nature conservation (OOSTENELD, 1985). Thus it has been suggested that the NWWT should consider reducing the number of cattle permitted in the grazing license from 10 to 7 or 8. This still gives a stocking density above 1 cattle per hectare, but the grazing will only be present for 7.5 months each year whereas Oosteneld's figures assume all year grazing. This however may not necessarily be acceptable to the grazing licensee, who should be consulted in any discussions regarding proposals to reduce the stocking rate on the reserve.

Aerial photographs from 1958 show that the extensive scrub area at the back of the reserve is a recent phenomenon. Several scrub species including ash and sycamore seedlings are now present on the leeward side of the semi mobile yellow dune ridges. Although these seedlings do not pose much of a threat to the yellow dune communities, if they are allowed to proliferate they will stabilise the frontal dunes and shade out much of the smaller dune plants. Thus these tree seedlings should be removed. Over the fixed dune areas however, the present grazing regime has prevented any such rapid scrub colonisation.

From the results obtained (TABLE 3 & FIGS 11 & 12), it can be seen that the dunes of Morfa Bychan attract a large number of visitors; indeed recreation is one of the major uses of the dunes today, resulting in a pressure of use index of 53.6% (TABLE 3). This can be seen by the increase in the number of caravan parks and recreational developments around and on Morfa Bychan, such as the construction of the Golf course which covers much of the fixed dune area outside the nature reserve. Due to the intensive recreational pressure that

the dunes experience, the overall conservation interest of the site is being adversely affected. This is illustrated in fig 11, where it can be seen that the pressure of use at 53.6% is not addressed by the small level of protection afforded to the site at 13.6% (TABLE 3). Anthropogenic induced erosion is not a significant problem at present, in the 17.6ha of the nature reserve but in the rest of the dune system, there are larger numbers of visitors and erosion problems are further accentuated by motor-cyclists and horse riding over the foredunes and across the strandline. Further problems have been created by the recently constructed concrete ramp that was installed to form a new beach entrance for cars at the eastern end of the dune system. The ramp is having a groyne-like effect similar to that of a small headland inhibiting sand migration and wave patterns. Due to longshore drift it has been noted that sand deposition is visibly higher on the western edge of the ramp (GARLAND, 1993). This suggests that the supply of sand to the foredunes is being impeded. This is likely to slow down rates of sand accretion and may have long term implications for the system as a whole. The foredunes are also vulnerable from wave attack, as car parking on the beach produces a smooth, hard surface over which waves can efficiently attack and remove the foredune.

The NWWT is trying to maintain the relatively limited visitor pressure experienced within the reserve as it is too small and fragile to withstand any significant increase of visitor pressure (GARLAND, 1993). They feel that limiting the actual numbers of visitors to the site is not very practical. However, they have stated that maintaining the limited pressure will be achieved by not promoting the site, to any extent other than by the provision of an interpretive sign explaining the ecology and the principle threats it faces. Along with this, they will be trying to repair all human damage to the reserve soon after the activity.

However this may not be a viable option if visitor pressure significantly increased, especially since the NWWT is a voluntary organisation with obvious financial constraints.

Taken as a whole then it can be seen from the discussion above and the results obtained (TABLE 3 & FIGS 11 & 12), that the dune system of Morfa Bychan is significantly out of equilibrium in respect to the level of protection it is awarded (13.6%) in response to the sites overall vulnerability (47.1%). It is a shame that only a small section of the system namely the nature reserve that occupies 17.6ha is under any direct management for conservation, for it seems that the rest of this important prograding dune system may ultimately be lost forever, without some level of management being implemented.

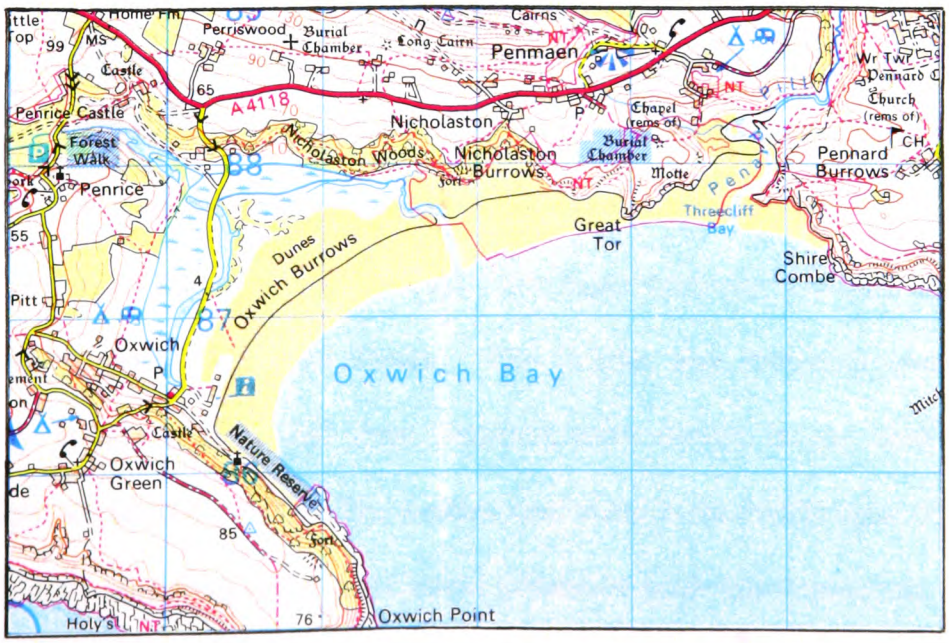
b)POSITIVE. ie VI/PM ratio <0.8 (TABLE 3, FIGS 13, 14, 17 & 18).

HIGH MANAGEMENT : LOW DUNE VULNERABILITY.

i)**Oxwich Burrows.** (VI/PM ratio 0.64)

Oxwich Burrows lie within the boundaries of the Gower Heritage Coast. Much of the sandy beach of Oxwich Bay together with the dunes, marsh, Oxwich Crawley and Nicholaston woods form the Oxwich National Nature Reserve, which covers about 300 hectares. The NCC established the reserve in 1963 following the completion of a Nature Reserve Agreement (NRA) with the Penrice Estate. Oxwich marsh and Dunes were purchased from the estate in 1986, in the same year Nicholaston and Crawley woods were acquired from the

PLATE 4
OXWICH BURROWS



Forestry Commission, with Oxwich wood continuing to be managed by the NRA (OSBORNE, 1987).

The dunes occupy 76.2 hectares, and are situated 10 miles from Swansea at grid references:- SS503865-SS513878. Most of the basic sand dune habitats are represented in Oxwich burrows:- Embryo, Yellow and Fixed dunes, Dune Slacks and Grassland. Due to this tremendous variety in the environmental conditions represented here, over 300 different flowering plant species have been recorded. This of course, is also assisted by the fact that the dunes are surrounded by a number of other habitats such as grasslands, marshes and woodlands that will act as a reservoir for some species which can spread into suitable parts of the dunes. The species variety is also assisted by the fact that the dune sand is rich in calcium carbonate (OXWICH INFO SHEET 3; 1983).

The sand was derived from the Bristol Channel where it was deposited during the Ice Age some 6-8000 years ago. At this time the sea level was much lower than at present, the Bristol Channel being reduced to a large river in the middle of a wide plain of birch tundra. Eventually the sea level rose, reworking these sands and pushing them shorewards (OXWICH MANAGEMENT GUIDE, 1990). The dune system developed as a series of parallel waves of sand increasing in size away from the sea. The dunes however, probably assumed their present form in early Medieval Times. The twelfth and thirteenth centuries were exceptionally stormy periods and deep blowouts were carved in the sand (OXWICH MANAGEMENT GUIDE, 1990). The weather moderated in the middle ages, and the dunes were traditionally used for grazing, until rabbit infestation made this impractical. During the Second World War the dunes were used by the RAF. They set up a series of lights

mimicking those of a nearby ordnance factory, to decoy enemy bombers. Further damage was caused in 1944 when the American Army occupied the area to rehearse for the Normandy landings (RANGER MAGAZINE, 1992). The resulting erosive scars took a long time to heal, thus, it was no surprise that in 1955, the northwest part of the burrows was described by a local botanist as a "wilderness of rolling mobile dunes" with "no vegetation to speak of" (OXWICH INFO SHEET 3, 1983 p 3). However, by the mid-sixties they had recovered much if not all, of their previous flora.

During the 1970's management activities were was concentrated in the frontal dunes and involved the usual programme of sand traps, planting Marram grass, and protective fencing supported by "Keep Out" signs. The dunes were also continuously patrolled at peak periods and visitors were asked to leave the enclosures (HUGHES, 1992). Re-stabilisation was more or less complete by 1981 with 90% stabilisation of the frontal dunes having been achieved, and for the rest of that decade the dunes were viewed as being in a satisfactory equilibrium between the three management objectives of maintaining the dunes **stability**, encouraging **diversity** and allowing **access** for recreation and education (RANGER MAGAZINE, 1992). However, the frontal dunes are now showing signs of losing diversity through over fixation, partly indicated by the score of 37.5% for the surface character of the seaward 200m (TABLE 3). The only exceptions were areas where human trampling had maintained a short turf with discrete open patches. This led to the idea that a reasonable level of public access actually could help diversity. Thus the original limited areas of access to the dunes were expanded with the use of trails, hides, viewing platforms, guided walks and permit systems, with "no go" areas limited to those areas where the natural interests are too fragile (HUGHES, 1991).

Other methods being used to address the problem of over fixation have been the eradication of bracken by regular mowing using a tractor and swipe; feral goats are being used to control invasive birch and alder in the dune slacks, and pony grazing has been introduced to help restore structural variety to the vegetation. Although grazing may produce a herb rich grassland, hovering around the mid-way in succession, it does not recreate earlier stages. So to re-establish these conditions "controlled disaster" management has also been undertaken, using a JCB to scrape an old slack down a couple of feet to fresh bare sand (RANGER MAGAZINE,1992).

The location of Oxwich burrows and the facilities that are on offer there, such as a sandy beach and sheltered bathing waters, (which are indicated by this site scoring the second lowest score of 19.4% for the condition of the beach (TABLE 3)) attract 250-300,000 day trippers and tourists, a year. Despite these statistics the burrows have a fairly low Visitor Pressure percentage of 28.6 and an overall Vulnerability index of 34.9% (TABLE 3). The factors which make it possible for the reserve to absorb these pressures include the following:

1)Most people come for beach activities and use a single large car-park. This allows the wardens to concentrate their facilities and wardening effort.

2)The resident local population is small, and there is no tradition of public access over much of the reserve.

3)The reserve has no highly fragile features which require intensive protection.

4)The site has failed to attract intensive research which although often valuable,puts pressure on reserve managers to discourage public access.

5)Public awareness and appreciation of nature conservation has increased. ie visitors are much more responsive to requests to stay out of dune restoration areas (HUGHES,1991).

This is obviously aided by the on site Reserve Centre which gives information and advice. This is also backed up by the Gower Field Education Project based at Oxwich which provides:

i)A day field visit service for schools in west Glam.

ii) Information for other field groups.

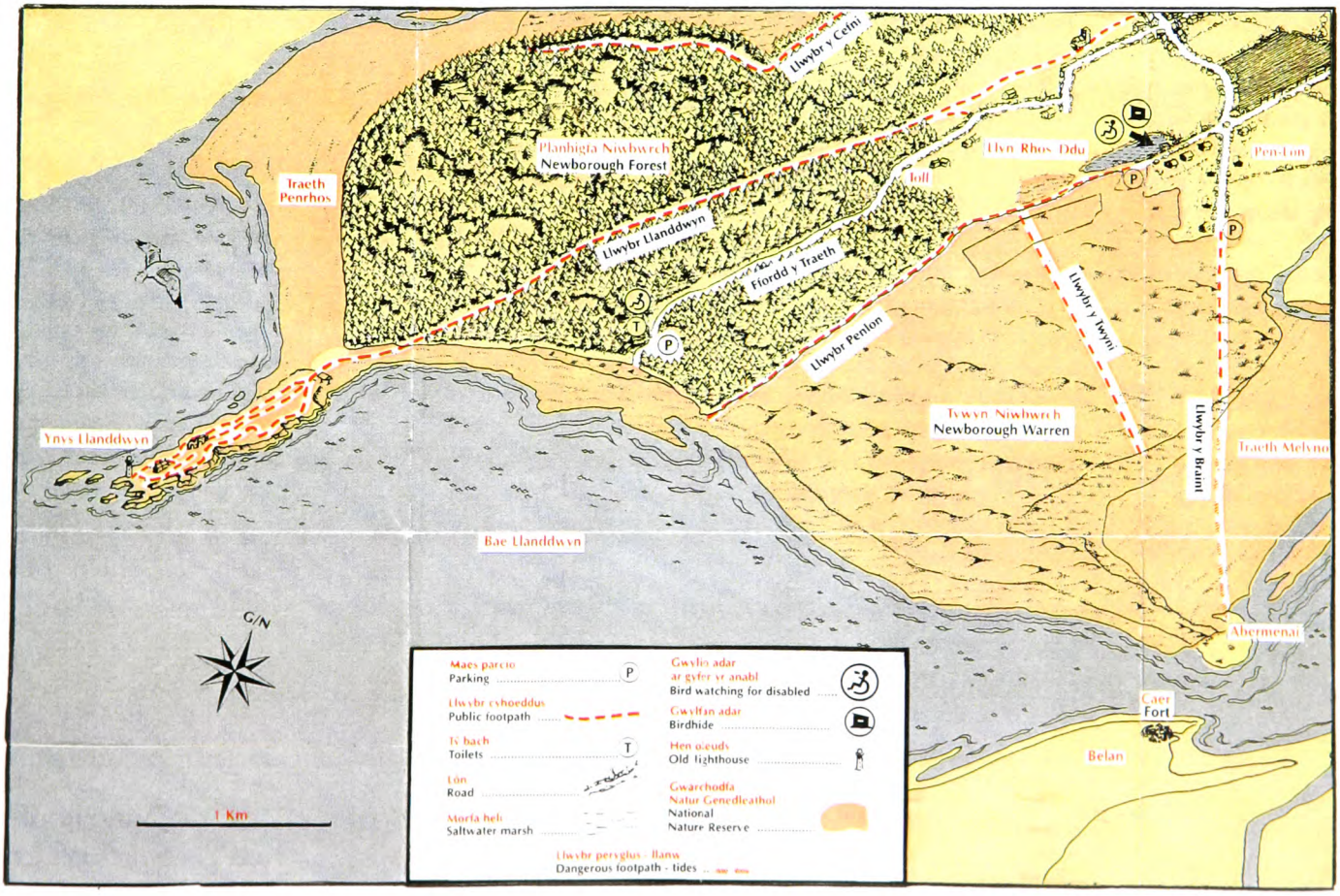
iii) Teaching resource material, with the field staff also providing management tours and illustrated talks on management (RANGER MAGAZINE,1992).

Site protection is also aided by the limited promotion of the site and its facilities, along with the procedure of moving one step at a time and reviewing the situation before progressing. Thus the protection that the site is given indicated by the index of 54.5% compared with the vulnerability index of 34.9 (TABLE 3), shows that it is possible to integrate a high standard of visitor facilities into an area of high nature conservation interest without significant loss of that interest.

ii)**Newborough Warren.** (VI/PM ratio 0.58)

Newborough Warren lies on the southwest coast of Anglesey, at Grid reference SH386655-SH443613, covering an area of approximately 1257ha, making this system the sixth largest dune system in Britain (HODGKIN, 1984). The Forestry Commission however, planted about 720ha of the western part of the dune system with conifers between 1947 and 1965. This area was not included in the checklist, therefore the results obtained are based solely on the remaining 537ha. The Warren's form is controlled by the Menai Strait to the east,

PLATE 5
NEWBOROUGH WARREN



Afron Cefni to the west and Ynys Llanddwyn, which divides the shoreline between Malltraeth Bay and Llanddwyn Bay.

Anglesey became separated from the mainland sometime between 5000-1000 B.C. The combination of a low coastline, retarded water flow at the mouth of the Malltraeth estuary and the southern opening of the Menai Straits, together with plentiful supplies of sand offshore in Caernarvon Bay, probably of glacial origin, favoured the development of the dunes along the Newborough Warren coastline. However, it seems that the development of the present dune system started in the fourteenth century, there after remaining in a semi-stable state (RANWELL, 1959). The first historical record of sand inundation in this area is quoted in Owen (1953 p 37), from Minsters Accounts 1152/4, temp. 1409 "About one third of the land of the manor was damaged by storm so thoroughly by the sea and inflow of sand as to render it useless of agriculture evermore..." In the sixteenth century, marram grass was planted in an effort to stabilize this mobile sand. An injunction was actually issued by Elizabeth I in 1561 for the mayor and bailiffs of Newborough to punish whoever was found cutting, uprooting or carrying away established marram (RANWELL, 1959). It seems however, that the dunes continued to be mobile well into the nineteenth century, when a visiting Dutch coastal engineer in 1890 noted that in the dune area "the whole mass of sand seemed to be moving (TUTEIN-NOLTHENIUS, 1890 p 7). A study of maps of the area going back to the late seventeenth century suggests that there has been no major change in the position of the south-west coastline of the warren since that time. So the spread of the dune system inland during the past 2.5 centuries seems to have occurred as a result of landward driven wind-blown sand rather than by any progradation of the shoreline (RANWELL, 1959).

The warren is roughly rectangular in shape with one of its long sides (the main coastline) more or less at right angles to the prevailing south-west wind. A narrow sand spit (Aber Menai) runs eastward to the Menai Straits from the south-west corner of the warren, and there is a ridge of Pre-Cambrian rocks running obliquely across the warren near the western end (RANWELL, 1959). East of Llanddwyn Island, part of the dunes are cliffed and experience net sediment deficit, while sand is transported eastward towards the spit at Aber Menai. The dunes at Newborough warren show the full development from strandline flora, dune ridges, wet and dry slacks to heath and scrub development. Other habitats include freshwater fen, saltmarsh and mudflats. The site hosts an outstanding vascular plant assemblage, including the endemic dune helleborine (*Epipactis dunensis)*, along with interesting lichen and moss communities. It also supports a very rich invertebrate fauna, particularly of Diptera, including at least 7 nationally rare species. The intertidal mudflats and saltmarshes adjoining the dunes at Traeth Melynog and Malltraeth sands are important wintering grounds for waders and wildfowl, regularly supporting over 1% of the British population of Pintail (SUMMARY MANAGEMENT PLAN, 1995). The juxtaposition and interrelationship of ancient rocks, dynamic coastal processes and diverse biological communities make this site an area of outstanding importance. In line with this, 633ha of Newborough warren was declared a National Nature Reserve in 1955, and is jointly managed by CCW and Forest Enterprise.

The site is intrinsically attractive to visitors, and along with the afforested areas is extensively used by recreational groups for walking, horse riding and shooting, and also for educational and research purposes. From the results obtained (TABLE 3) it can be seen that overall Newborough has a fairly low pressure of use score of just 25%. The site is able to

accommodate these large numbers of visitors by a number of implemented management objectives. For most of the site, visitor numbers have not reached saturation point. This is aided by the fact that access is effectively controlled by the availability of car parking spaces within the reserve. Visitor impact is also being reduced through the limitation of entrance points to the site. Access through the dunes is for the most part restricted to broadwalks and footpaths, with entrance to the rest of the system being by permit only. Due to the proximity of the education centres at Aberffraw and Ynyslas promotion of the site is kept at a low key level. There is a small museum and interpretation centre at Ynys Lladdwyn, which is situated about 2.5Km from the westward dunes. There are also a number of signs and information boards around the reserve to keep visitors informed about the site. The wardens then supplement this with a number of talks, slide shows and guided walks. One of the major problems facing the site, as with many dune systems, is that of over fixation and scrub encroachment. Since 1954 with the advent of myxomatosis the once vast rabbit population was all but decimated. This had a subsequent effect on the flora, with there being an overall decrease in the number of species present in a fixed area (RANWELL, 1959). The rabbit population is still at a low level and thus the reduced level of grazing is not enough to abate the scrub encroachment on the dunes. In order to help alleviate this problem approximately 1/3 of the open warren is grazed with sheep, ponies and cattle. This is further aided by scrub cutting and spraying. Another aspect of current concern of the open dune system to the east of the plantation, is the likelihood of regeneration and spread of Corsican pine. This species does not flower until it is between 20-25 years of age and generally does not produce a heavy cone crop until 25-30 years. Most of the Corsican pine was planted between 1953 and 1956, and is likely to start fruiting freely at any time. Prolific natural regeneration of this conifer has occurred in other dune systems, eg at Holkham NNR in Norfolk where a

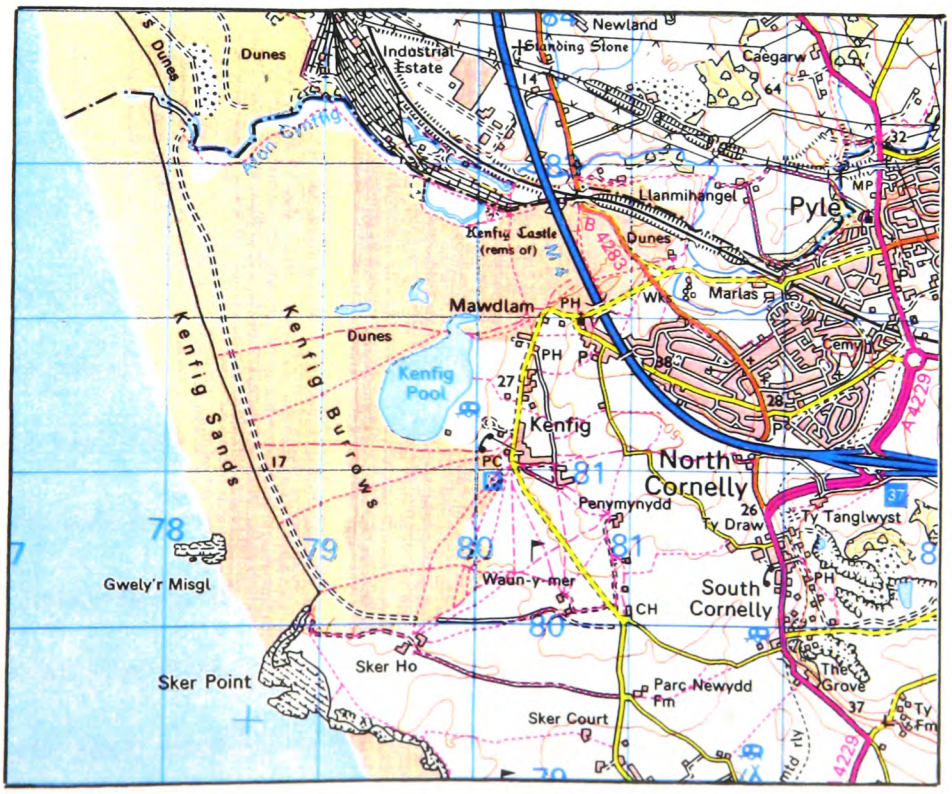
plantation was established between 1870 and 1891, so it could also become a serious management problem at Newborough (BLACKSTOCK, 1985), unless appropriate management is undertaken to prevent pine colonisation.

From Table 3 and Fig 13 & 14 it can be seen that despite the management problems encountered on site, the level of protection given at 53.6% far exceeds the site vulnerability, calculated at 31.4%. As stated in the Summary Management Plan (1995), the management of Newborough is mainly directed at maintaining, for a sustained period, the dynamic nature and species diversity of the site. In harmony with this a programme of controlled grazing and scrub control with comprehensive monitoring is seen to be the key component in this management hypothesis. In view of the present problems encountered at the site, and the predicted future problems that could arise (such as the effect on the wet slack communities, with the continuing impact of the forest on the water table), this management regime coupled with continuous monitoring will keep the potential increased vulnerability of the site well within the parameters of the protection allocated.

iii)**Kenfig.** (VI/PM ratio 0.69)

Kenfig burrows are situated on the eastern side of Swansea Bay, 7Km south-east of Port Talbot and 2Km north-west of Porthcawl, at Grid reference SS790834-SS786796. The dunes cover an area of approximately 627.4ha, being the largest hindshore type dune system in South Wales, and one of the largest in Southern Britain. This area is privately owned by the Kenfig Corporation Property Trustees, and was designated an SSSI in 1954. In 1978 513ha of the SSSI became a LNR, before being designated as a NNR in 1989, managed under

PLATE 6
KENFIG NNR



lease by Mid Glamorgan County Council. The site was also proposed as a Special Area of Conservation under the EC Habitats and Species Directive on March 31st 1995.

The reserve's western edge borders the sea, where a shingle ridge at high water mark is overlooked by an eroding foredune cliff, which accounts for the site obtaining the highest score of the condition of the beach at 75% (TABLE 3). Immediately east of this cliff is a ridge of dunes running parallel to the coast. Interspersed among these ridges are many low-lying flat dune slack complexes. The foredunes are separated from the rest of the system by the Haul road that was constructed in the 1960s. The site mostly comprises fixed dunes and slacks, however each of these extensive system habitats is unique due to differences in geomorphology, hydrology or successional stage. Variations also occur within each dune slack in the form of blow-outs, dune aspect and slope etc.. The reserve also includes the 28 hectare Kenfig Pool, the largest natural freshwater body in Glamorgan. The pool is partially surrounded by encroaching reedbeds, with a gradual east to west succession of open water through reedbed to willow scrub on the pool's western edge. Other habitats represented on the reserve include; grazed saltmarsh, *Betula* Sp. Woodland, *Populus tremula* woodland, *Alnus glutinosa* carr, patches of mature *Hippophae rhamnoides*, river and industrial wasteland. In total, this habitat variety is reflected by a great floral and faunal diversity. There are over 600 species of flowering plants and ferns which comprises 45% of the entire British species list. Over 20 of these species are notable. One such species is the Fen Orchid (*Liparis loeselii*) whose population at Kenfig represents 95% of the UK population (WILLIAMS pers comm). The majority of the invertebrates have not been well researched, but there may be over 2000 species, with over 100 notable species having been recorded. It also supports good numbers of bird species, both breeding, wintering and migrants.

Important breeding species include the Lapwing, Ringed Plover, and Snipe.

The formation of this system occurred in the same way as the formation of Merthyr Mawr, which will be considered later. The rise in sea level that continued throughout the Neolithic and Bronze Age periods, must eventually have resulted in the breaching of the off-shore sand bars and islands. This remobilised large quantities of sand which migrated landward to initiate the formation of the current system at approximately 3000yrs B.P. There is abundant evidence that Kenfig has been inhabited by man for at least 4000 years, such as the discovery of stone axes and other such tools (JONES, 1995). However it seems that the first settlement did not occur until around 800 A.D, with the occupation of the Danes. It has been suggested that the name Kenfig actually originated from the Danish origin meaning the bend in the river Ken. The first castle was built from wood in the reign of King Stephen (1135-1154). The parish church was also created in the same period (JONES, 1995). Kenfig became incorporated as a Norman Borough in 1147 and was an important maritime trading town, with regular weekly markets and two annual fairs. The Welsh considered it a threat and attacked it many times resulting in the wooden castle being replaced by a stone tower in about 1185. The site was severely affected by sand encroachment from around 1316, so much so that by 1470 the town and farmland were overwhelmed. Attemps to prevent the inundation was by the planting of rushes and sedges, such as marram grass, but this was unsuccessful and the "great" storm of 1607 completed the burial of the town. The dunes gradually became vegetated and successive users used the common for stock grazing. This activity has subsequently declined in recent years due to the demise of the burgesses, general lack of demand from "local inhabitants" and an increase from £2-£12 per head per annum for sheep grazing rights (JONES, 1995).

Modern use of the system in the 20th Century has included Allied Troop training during the Second World War. There was also regular use of the area by the Police in the 1950s and 1960s for motorcycle training. Although this damaging activity has now ceased, it has unfortunately been replaced by the illegal use of scramblers and off-road vehicles. The site was further disturbed by the laying of a pipeline from Kenfig Pool to supply the Steelworks situated to the north of the reserve. The pipeline however, was never used due to the construction of the British Steel reservoir at Eglwys Nunydd. A haulage road was also constructed across the foredune area from Cornelly quarries to the Port Talbot iron ore terminal in 1962. This greatly affected the sand movement and accretion of the site, and continues to do so. The road was scarified in 1977 and now natural recovery is gradually taking place, with it becoming progressively overgrown and covered by wind-blown sand. The site now is mainly used for recreational and sporting activities, attracting up to 250,000 visitors per year (JONES, 1995).

Many people use the site to walk their dogs, focusing their activities around the southern dunes and pool in particular. As a result the first 100 yards or so from the car park can be extensively fouled with dog litter (JONES, 1995). In summer, site activity increases with people using the pool and its southern sandy "beach" for swimming and sun-bathing. Many visitors seem unaware of the sites conservation importance which may be a causal factor in abuse such as litter, trampling, vandalism, use of off-road vehicles, and fires. This is also reflected by the lack of interest in conservation walks, talks and other free events organised by the site staff (JONES, 1995). Despite these statistics, results obtained at Kenfig show that overall the site has quite a low pressure of use at 28.6%, well within the confines of the level of protection afforded the site at 59.1% (TABLE 3). This is probably due to the fact that

visitors tend to be concentrated around the southern end of Kenfig pool and around the southern dunes. The northern end of the reserve is very infrequently used, despite there being no restrictions on access to any part of the dunes. The lack of conservation awareness of the average visitor may be partly attributed to the fact that at present it is difficult to persuade the majority of people to visit the site's visitor centre more than once. This may be because the current exhibition is aimed at a "New Scientist" level adult audience, which comprises only a small percentage of the overall visitors to the site. Also many of the signs and leaflets are out of date and only in English, rather than bilingual. The problem is further compounded by the lack of outdoor information boards, but limited financial resources prohibit the provision of these outdoor information boards, which in the past have often been vandalized or stolen. However, the Visitor Centre is currently being updated. The renovated Centre will have more "hands on" exhibits, modernised leaflets and an indoor viewing hide. New outdoor facilities are also being created to allow access for the disabled, as the terrain of the reserve currently restricts any access (JONES, 1995).

The main problems at Kenfig, centre around the loss of bare sand and over fixation which is reducing the current diversity (JONES pers comm). Dunes are naturally dynamic, created by blown sand and fixed for short periods of time by vegetation before again becoming unstable. Active dune systems thus exhibit diverse age structure, varied hydrologies, and habitats. Kenfig has very few bare sand habitats on the reserve. The system is approaching successional climax, and thus diversity in some areas is decreasing below previous maxima. This is illustrated by the loss of at least 6 species from the reserve, and the critically low populations of certain species such as the scarce *Sisrinchium bermudiana*. A lack of new sand supply accompanied by net erosion of the foredunes since before 1970, is compounding

this long term succession problem. There is a minor amount of accretion but this is limited to an approximately 300m stretch of the 3000m frontage. Elsewhere foredune loss is probably in the order of 1m/yr [this factor is highlighted in Kenfig obtaining the highest score of 75% for the condition of the beach (TABLE 3). Interestingly this is the only section in which the management does not compensate for the existing conditions encountered (FIG 13 & 14)]. It can be seen that Kenfig will therefore not regain its previous active nature without management. Grazing by rabbits or sheep would help to reduce scrub encroachment, but the rabbit population was severely reduced by myxomatosis and has not been able to recover. Sheep numbers are also low due to prohibitive grazing conditions such as cost, and the lack of any perimeter fencing. The only solution to this over-fixation is an active management approach which includes, continual mowing and scarification.

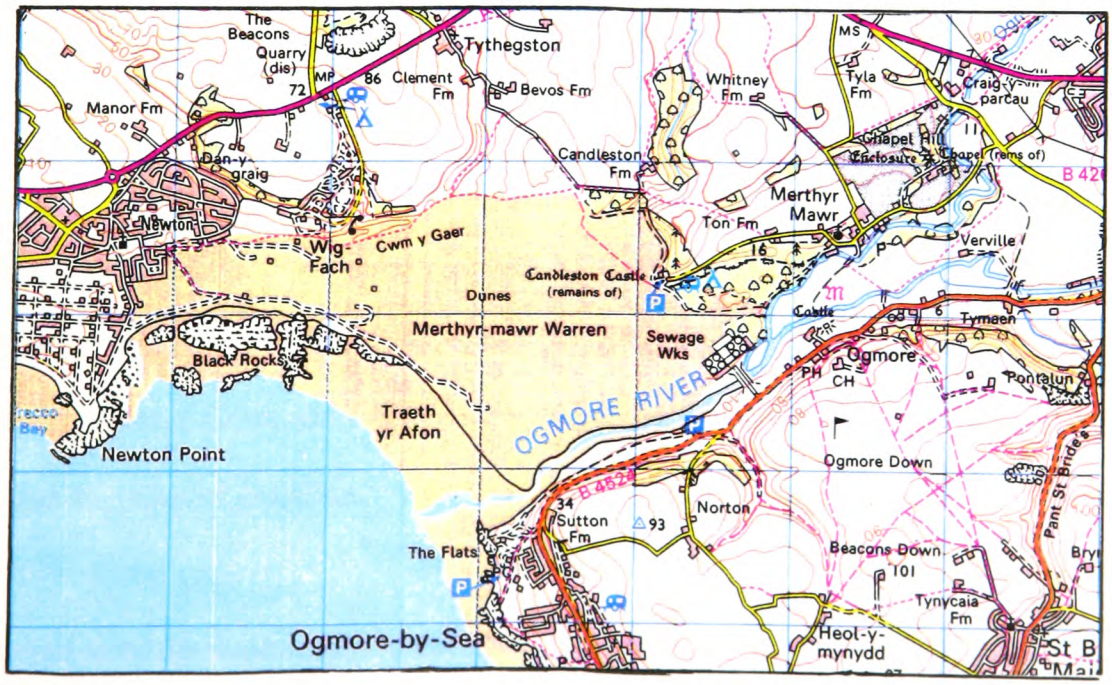
The overall results obtained indicate that the site has a high amount of management (59.1%) compared with the overall vulnerability calculated at 41.3% (TABLE 3). It can however be seen that Kenfig is a high maintenance site, and that if it is to maintain its diversity in both habitat and vegetation etc. then this high level of management can be justified.

2)SYSTEMS IN MANAGEMENT EQUILIBRIUM.

ie VI/PM ratio 0.8-1.3. (TABLE 3 & FIGS 19, 20, 21 & 22)

MANAGEMENT IN LINE WITH OVERALL DUNE VULNERABILITY.

PLATE 7
MERTHYR MAWR



i)**Merthyr Mawr.** (VI/PM ratio 0.88)

Merthyr Mawr Warren is the most easterly surviving fragment of the once extensive South Wales dunes. The dunes cover an area of 341.88 hectares and are situated at grid references SS846787-SS874784, between the resort town of Porthcawl and the mouth of the River Ogmore. At Newton Burrows/Merthyr Mawr Warren, the system abuts the Carboniferous Limestone scarp on the north side of the Ogmore valley. The dunes have therefore formed at an extremely high level(>60m) resulting in a wide range of groundwater conditions, the most obvious feature of which are the numerous slacks which provide a wide range of habitats. The dunes at the western half of the burrows are comparatively stable, becoming less and less so as you progress easterly. At the dunes most south easterly edge, the dunes border the salt marshes of the Ogmore Estuary providing a further range of habitats (LLEWELLYN, 1986). However, due to the lack of sensitivity in the post construction restoration of the sewage pipeline that was laid across the dunes and saltmarsh in 1988, the main creek in the central saltmarsh embayment has been blocked, impeding the flow of spring water from the dunes to the Ogmore Estuary (JONES, 1989).

Merthyr Mawr was declared an SSSI in 1953, as large populations of calcareous plants (including 8 species of Orchid) and large numbers of bryophytes, grasses and herbs are found here, along with a rich invertebrate population (Williams and Randerson, 1989). In 1973 the Glamorgan Heritage Coast was designated, with the dunes forming the western border of the designated 14 miles of coastline.

The formation of the dunes began about 6000 years ago. During the first Ice Age (2 million

years ago) the Bristol Channel was created. An immense river valley, it was continuously flooded and dried during the next three Ice Ages. After the last Ice Age sea level increased due to global warming. The 14,000 years of warming have resulted in an increase in sea level by 45m. During this time the glacial debris in the form of sand was washed on to what is now South Wales. There is strong evidence to support the view that Merthyr Mawr was settled during the Palaeolithic or Mesolithic period, as evidence of polished stone axes and pottery have been found dating back to this period (GILLHAM, 1987). Fox (1927) determined that Iron age man settled in this area between 400-200BC, when the lower dune area was covered by some 2m of sand. The Celts used the escarpment and dunes as a defensive encampment. In the 11th century the Normans arrived and advanced to the Ogmore river. At the confluence of the Ogmore and Ewenny rivers a wooden castle was built. During the Norman period the dunes would have been 4m high. Between the 13-16th centuries large influxes of sand occurred as a result of the general storm periods then existing in Europe, however by the late 16th century cattle grazed on the lower dune portions. In the 19th century further storms moved sand into Candleston village. To arrest the problem growth of the dunes extensive planting of trees occurred around the Merthyr Mawr estate. A large rabbit population existed at the time, so much of the area was denuded of vegetation. In 1840, sea buckthorn (*Hippophae rhamnoides*) was introduced in an attempt to combat erosion. However, it was not until the first World War when the dunes were used as shooting grounds, that the dunes were stabilised. Over the last 35 years the almost complete absence of rabbits due to the advent of myxomatosis, has led to dune rejuvenation. Sand and gravel extraction from the frontal dunes took place between 1937-1972 giving rise to several large blow-outs, especially in the east (WILLIAMS and RANDERSON, 1989). Unfortunately the gravel areas at the western end of Newton burrows are constantly being

disturbed preventing the development of a diverse flora, that has been associated with the totally abandoned workings further east (JONES, 1989).

"Merthyr Mawr is one of the main recreational lungs of industrial South Wales" (WILLIAMS and RANDERSON, 1989 p217). Thus recreational pressure is potentially high with 1.5 million people living within 2 hours drive, the maximum daily distance that people are prepared to drive from their homes according to Dower (1970). The potential visitors to the site is also heightened by the fact that neighbouring the dunes is the largest holiday caravan park in Western Europe. However despite this the results indicate a comparatively low visitor pressure index of 32.1% (TABLE 3).

The main access to the dunes is from Candleston via Merthyr Mawr village, with there also being foot access from Newton village. Main visitor usage of the dunes is that of walking and child's play (WILLIAMS and RANDERSON, 1989). Recreational surveys conducted by Williams and Sothern (1986) have shown that most visitors are concentrated within 250m of Candleston car park and in a line from the car park to the beach. The immediate hinterland of Candleston has been denuded of most of its vegetation as a result of the recreational pressure, ie, children sledging down the big dunes. However, these large areas of bare sand that are being maintained are unlikely to cause any long term problems(JONES, 1989). This localising of the visitor pressure and the lack of long term problems associated with the areas of bare sand, contribute to the comparatively low visitor pressure index recorded.

The ethos of Heritage Coasts is to persuade landowners to voluntarily cede part of their

domain on a non-statutory basis to the relevant Heritage Coast authority. Therefore any management work undertaken by on site Rangers can only be performed after consent is gained from the landowners. This may not always be forthcoming, especially since the Trustees of Merthyr Mawr estate wished to form a 12-18 hole golf course on the foredune area. This proposal would have an irrevocable and dramatic impact on this sensitive dune system, and one that is in direct conflict with the policies of nature conservation at the site. Fortunately three previous planning applications have been refused, so it is hoped, will any future applications(LLEWELLYN, 1986).

The site is also under threat from the introduced species, sea buckthorn (*Hippophae rhamnoides*). Because of the reduced rabbit population, this invasive species is no longer kept under control and has taken over large areas of the dunes and shaded out much of the original flora with its blanket cover,changing much of the open dune system into an impenetrable thicket, which is increasing by 2ha/yr (WILLIAMS pers comm). This fact is illustrated by the score of 45.8% being recorded for the surface character of the seaward 200m (TABLE 3). About 4 years ago a large thicket area was eradicated by 'hand pulling' the results have been quite pleasing with a return of the ground flora, and it is only now that small seedlings are starting to occur again. Although 'Hand pulling' seems to be quite effective, it is a slow job involving much man power. Because of the extent of the problem encountered at Merthyr Mawr, it is not a very viable one,thus it is hoped that permission can be sought from the Trustees to bring in JCB's to extract the large thickets.

Although the results obtained here place the dune system in equilibrium with respect to the vulnerability of the site (38.4%) and its protection measures (43.2%) it can be seen that if

the site is not to be further degraded then constructive management for nature conservation needs to be increased. Unfortunately the correct management of Merthyr Mawr is unlikely to be achieved until either:-

1) The site is declared a Local Nature Reserve (LNR), and is provided with sufficient funding to maintain several permanent ground staff.

or

2) The staff are given the remit of running Merthyr Mawr on an LNR basis over and above the current responsibilities for the site as an integral part of the Heritage Coast (Jones, 1989).

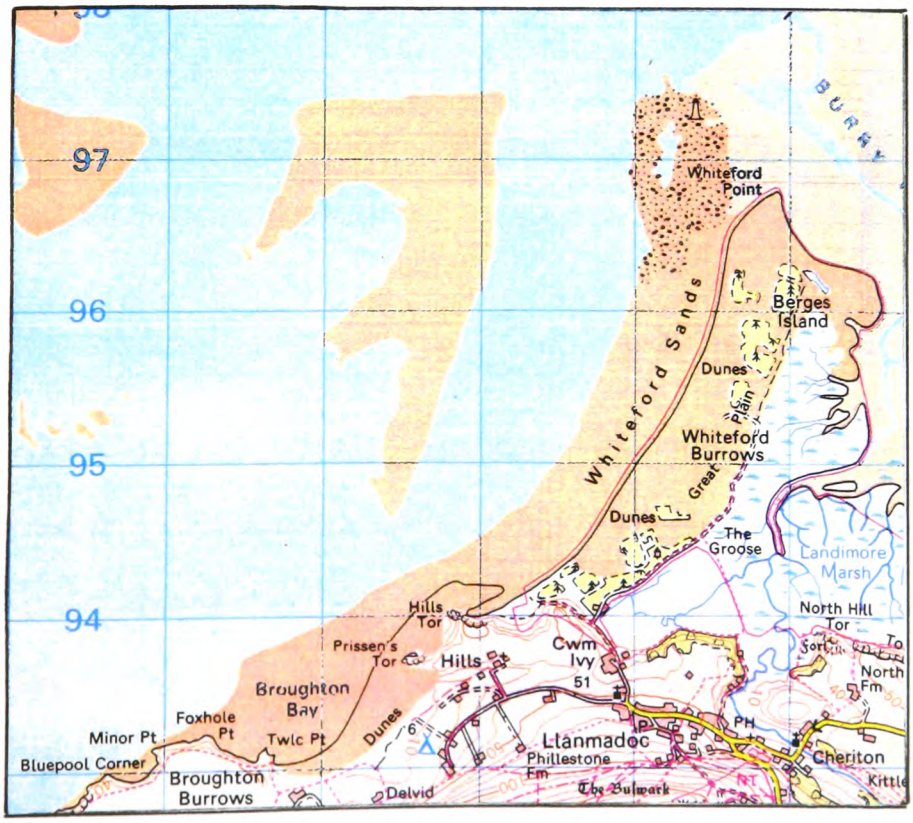
Steps are being taken to redress the problems of managing the site, as it has been stated that preparation maybe made to designate the site as a National Nature Reserve(NNR) (JONES pers comm).

ii)**Whiteford Burrows.** (VI/PM ratio 1.02)

Whiteford Burrows (known locally as Whitford) are a relatively secluded and undisturbed area of calcareous dunes forming at the seaward end of the Burry Estuary on the north coast of the Gower peninsula. They cover an area of approximately 142 hectares at grid references SS429940-SS448967.

The National Trust, with the assistance of the Glamorgan Trust for Nature Conservation purchased Whiteford point in 1965, the first property acquired under Enterprise Neptune. In 1967 the Nature Conservancy Council leased about 120 hectares of the burrows from the National Trust and in 1969 declared them as a National Nature Reserve(OSBORNE, 1987).

PLATE 8
WHITEFORD BURROWS



The Burrows have been fed with sand from the beach (Whitesand bay) immediately in front of them by the prevailing westerly winds. Davies (1879) showed that the Whiteford burrows were in existence in 1661, when tenants were required to assist in fixing them, and has also pointed out that the evidence of rapid changes in the neighbourhood suggests that the 'new Burrows'(the most seaward portion) were formed very recently.

All major dune forms are well represented- embryo, mobile and fixed dunes, dune grassland and slacks. The largest dunes occur in the North-east where a group of 'wandering dunes' reach a height of more than 24m. From here a broken ridge, some 10-16m high, runs down the centre of the spit, spreading out at the southern end into an area of slightly higher ridges. There are about 105 slacks varying in size from 70 to 40,000 square meters, running in two distinct chains along the axis of the spit. Approximately 20 hectares of the dunes were afforested with plantations of Scots pine, Corsican pine and other introduced conifers between 1955 and 1964. These were planted to absorb visitor pressure, and although they are able to do this, they shade out indigenous dune and slack communities and threaten to spread to other areas as they reach the age for seed production. The management policy now is to gradually remove the plantations to encourage the return of the native dune species and communities.

Due to this array of habitats, Whiteford has a diverse collection of wildlife. It is home to an extremely rare liverwort (*Petalophylum ralfsii*) and it is the only known site in Europe for a living population (other sites have only produced shells) of the tiny snail *Vertigo angustior* (Adian Y Ddraig, 1994).

To ensure a healthy and balanced vegetation at the site, grazing is an all-important feature at Whiteford. Ponies and sheep enter the burrows from the neighbouring Landimore and Llanrhidian saltmarshes to the east, which are part of a registered Common with a long history of grazing. The burrows are not subject to these common rights, but previous land owners grazed sheep on the dunes. Although this controlled grazing had ceased by the time that the NNR was established, ponies and sheep still freely enter the dunes, with up to 90 ponies and 40 sheep being recorded at various periods (DAVIES *et al*, 1985). After the introduction of myxomatosis, rabbit populations grazing the burrows have oscillated. When populations have reached a high level, a carefully controlled culling programme is instituted to prevent populations reaching levels which could induce severe erosion and damage. The the combination of rabbits, ponies and sheep, has produced a level and grazing pattern that is in good balance with the dune system. Although the grazing is largely uncontrolled, it is very suitable for retaining the variety of flora and structure of habitats necessary for other wildlife interests, such as invertebrates.

Because of its remote nature the pressure of tourism is generally light, since access to the area is not easy, and is limited owing to very small car parking facilities in the area. This lack of tourism is highlighted in the low visitor pressure index of 17.9% recorded at the site (TABLE 3). Management of the area is geared to promote quiet enjoyment of the natural features and so interpretative information is limited to 1 board at the entrance to the reserve (OSBORNE, 1987). Comparison of the Vulnerability index (32.6%) and the Protection index (31.8%) (TABLE 3; FIG 19 & 20) indicates that the site is in equilibrium. This has been due to the effective management of the site where a more or less ideal grazing regime with ponies and rabbits has established. Also the main management problem identified at the

VULNERABILITY AND PROTECTION PLOTS FOR SELECTED SITES IN MANAGEMENT EQUILIBRIUM

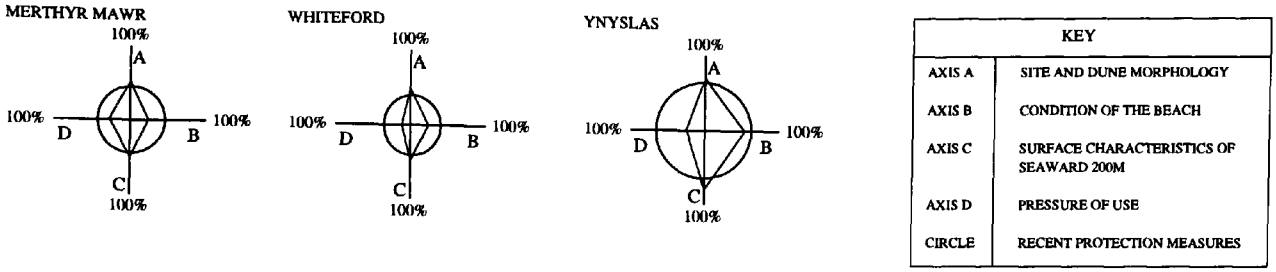


FIG - 19

VULNERABILITY AND PROTECTION INDICES FOR SELECTED SITES IN MANAGEMENT EQUILIBRIUM

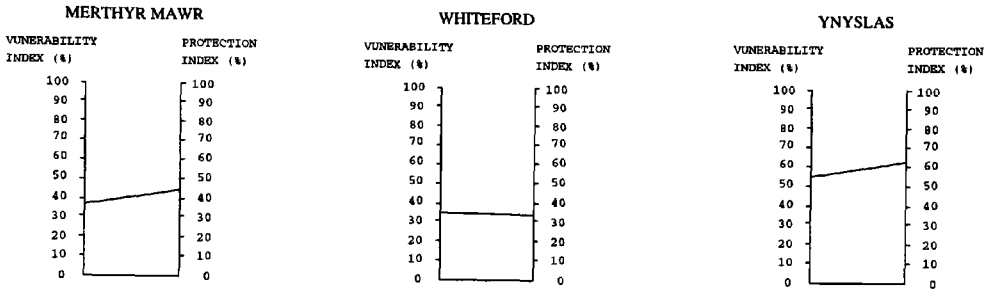
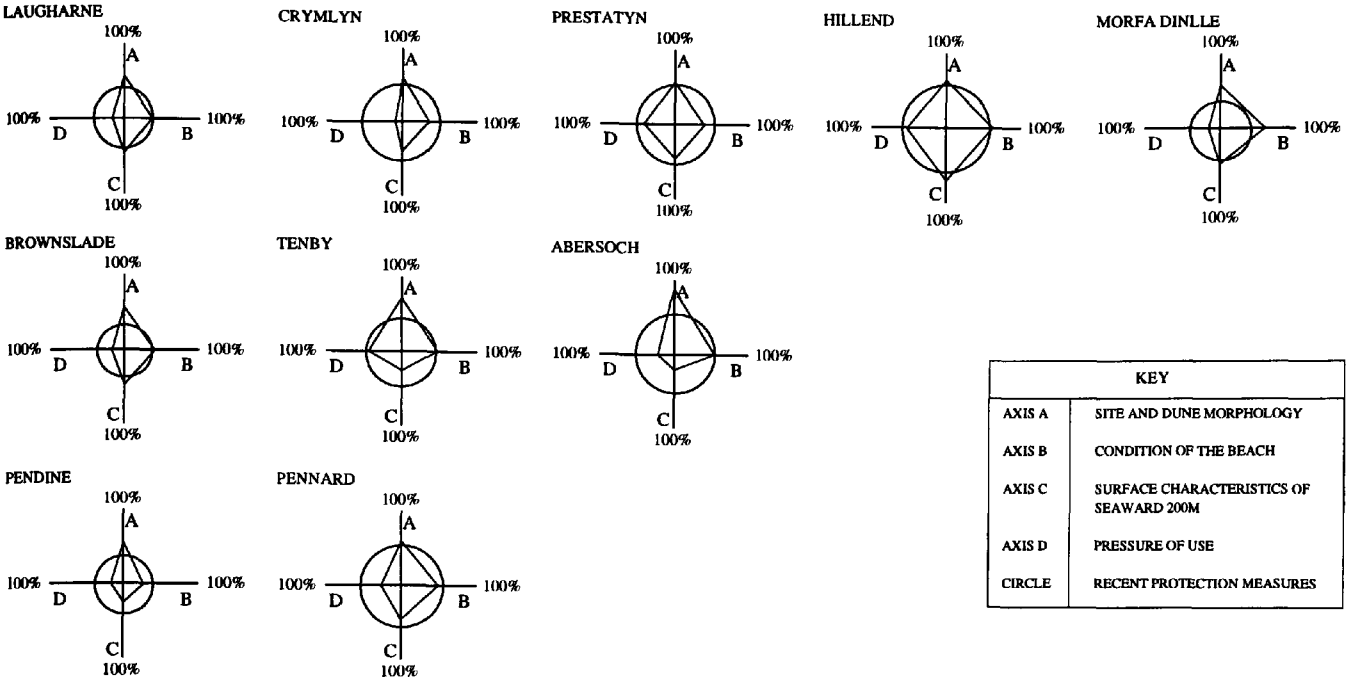


FIG - 20

VULNERABILITY AND PROTECTION PLOTS FOR REMAINING SITES IN MANAGEMENT EQUILIBRIUM



KEY	
AXIS A	SITE AND DUNE MORPHOLOGY
AXIS B	CONDITION OF THE BEACH
AXIS C	SURFACE CHARACTERISTICS OF SEAWARD 200M
AXIS D	PRESSURE OF USE
CIRCLE	RECENT PROTECTION MEASURES

FIG - 21

VULNERABILITY INDICES FOR REMAINING SITES IN MANAGEMENT EQUILIBRIUM

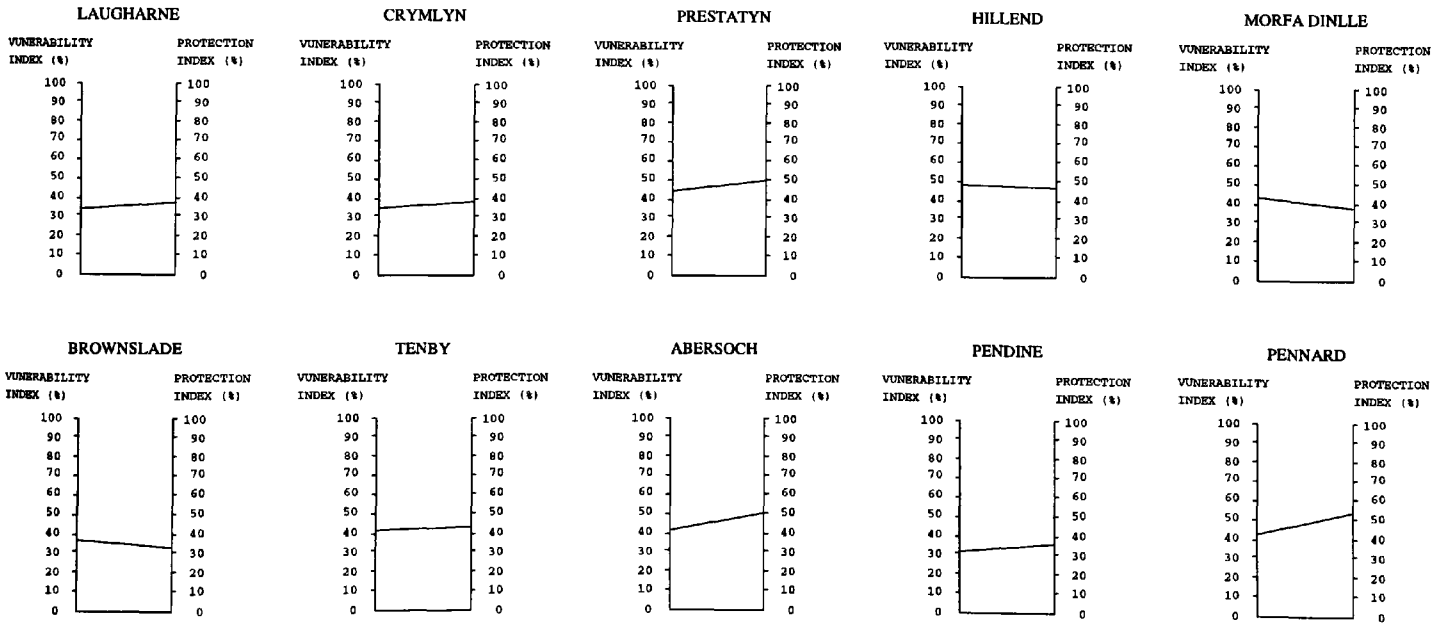


FIG - 22

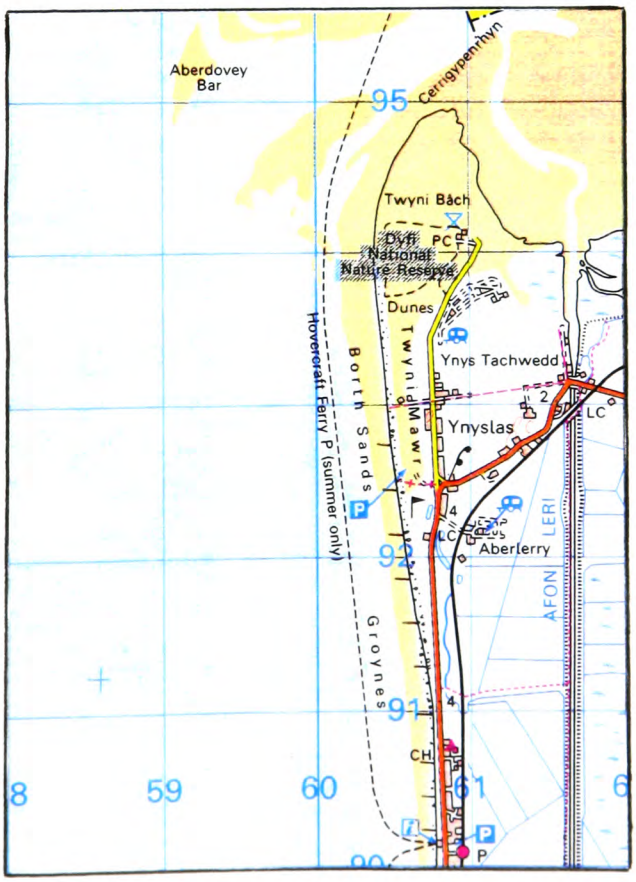
site, the afforested areas, are being effectively reduced (JONES, Pers.comm.).

iii)**Ynyslas.** (VI/PM ratio 0.92)

The dune system at Ynyslas forms part of the Dyfi National Nature Reserve (NNR) and was established by the Nature Conservancy Council (NCC) in 1969, and is now managed by the Countryside Council of Wales(CCW). The reserve also consists of the sand and mudflats which make up the Dyfi Estuary along with Cors Fochno; a raised peat mire. The dunes occupy 68.22 hectares of the reserve and lie at grid reference SN608946-SN607921.

The date of their initial development is difficult to determine, although most of the dunes at Ynyslas have been forming since the 13th century, on and behind a shingle ridge (YNYSLAS STUDENTS GUIDE,1992). After the retreat of the great Ice sheets the Dyfi Estuary became colonised by reed swamp, but over the following 4000 years Alder Carr and Birch scrub gradually became dominant, which were then taken over by a pine and oak forest. By this time a shingle spit had begun to develop from Borth cliffs composed of debris left behind by the glaciers. This spit was pushed inland as the sea level rose and encroached upon the woodland (CEREDIGION COASTAL HERITAGE, 1983). The water logged conditions prevented decomposition and mosses built up into thick deposits of peat which buried dead trees. Anaerobic conditions preserved some of these tree stumps, forming the 'submerged forest' which can be seen on the beach 1m below ordinance datum, 1Km south of Ynyslas. To the east the *sphagnum* dominated mire, continued to develop into a dome shaped raised mire (Cors Fochno). The dunes started to grow just north of Borth, but they have now been levelled and form the southern half of the Golf course. The dunes then began to form at the

PLATE 9
YNYSLAS NNR



northern end of the shingle ridge. In 1824 the River Levi was canalised into the Estuary and the spit and dunes to the north were stabilised and the Twyni Mawr rapidly grew in size. The dunes are still expanding in bursts, partly it seems in response to groyne building (CEREDIGION COASTAL HERITAGE, 1983).

The population in and around what is now the Dyfi National Nature Reserve was extremely low until the beginning of the last century. Ynyslas was considered wasteland and only roughly grazed by rabbits. However, the level of road access was high as it was an important point for crossing the estuary to Aberdyfi. The arrival of a railway to Borth in 1863 brought the tourist industry to Borth and more use was made of Ynyslas as a holiday resort.

In 1939 the army used the dunes to test weapons and tanks. They built a road to the dunes and huts and concrete constructions, the remains of which were removed during the 1970's.

After 1945 the rapid growth in cars/caravans/leisure brought about a marked increase in summer visitors. There was indiscriminate parking in the dunes as well as a litter problem and uncontrolled shooting (YNYSLAS STUDENTS GUIDE,1992). A marked deterioration in the quality of the system took place, indicated by the two major blow-outs that occurred and can still be seen today. This happened when people drove cars and walked to the beach from the caravan site that was erected to the south east of the dune system. This deterioration is also borne out in the results, with the system scoring the highest index for the surface character of the seaward 200m at 79.2% (TABLE 3).

The dunes attract some 250,000 visitors and 8000 school or university students per year, but despite this the dunes have a low Pressure of Usage index of 32.1% (TABLE 3), which must be attributed to the management that is carried out to try and minimise visitor impact:- Vehicular access onto the beach is only permitted on the east side of the dunes. Vehicular access into the dunes or around to the west side beach is strictly controlled by roadside banks and fences along with bollards (CEREDIGION MANAGEMENT 3,1979).

In an attempt to control indiscriminate public access throughout the dunes the Nature Conservancy provided a 1.5 mile Nature Trail with pamphlets obtainable from the information centre. Boardwalks have been constructed to provide a number of routes to the beach to prevent trampling effects. Along with interpretive leaflets there are a number of signs around the Reserve provided to encourage people to respect their surroundings and have a greater understanding of wildlife and nature conservation. One such board introduces "Mr & Mrs Marram Grass" to the public in an effort to educate them about dune restoration. The Staff at Ynyslas also offer conducted tours and guided walks along the Nature Trail(GOOD BEACH GUIDE,1991).

The dunes also have a problem with rabbit grazing, and to prevent over grazing a small number of rabbits are culled every year to try and keep the numbers in a reasonable balance (YNYSLAS STUDENTS GUIDE,1992).

The management at the site, which had an index of 61.4% seems to be quite effective in controlling the degradation of the site as it compensates for the overall vulnerability of the site at 56.4% (TABLE 3; FIG 19 & 20), leaving the site in an equilibrium situation.

CHAPTER 8

CONCLUSION

Wales' coastal dunes are an important resource not only as significant habitats in their own right, but also because they provide areas where a wide variety of specially adapted and rare plants and animals occur. These dunes are also important for recreation, sea defence and agriculture. These uses are not however, always compatible and historically much of the sand dune landscape has been destroyed. Despite the enormous losses it is not too late, for by managing the remaining areas in a sympathetic way their survival not only for wildlife but also for the benefit of humans should be ensured.

An objective assessment of the environment is necessary for effective management of dune systems. The vulnerability checklist provides such a management aid, which summarises the present condition of the dune system and due to its ease of use it can be applied by both specialists and non-specialist alike. The first 43 parameters of the checklist (TABLE 1), which are comprised of the dune morphology, beach condition, surface characteristics of the frontal 200m of the dunes and pressure of use, are summated to give a Vulnerability Index (VI). The remaining 11 parameters (TABLE 1) provide the Protection Measure Index (PM).

Results shown in Table 3 indicate that the VI indices ranged from 4.3% (Broadhaven) to 65.1% (Morfa Dyffryn), and the PM indices went from 13.6% (Morfa Bychan) to 68.2% (Conway). Interestingly 48% of the dunes investigated demonstrated that they were in

management equilibrium. Of the remaining 14 sites that were found to be out of management equilibrium, 30% exhibited a low vulnerability to a high management regime, and 22% displayed a high overall vulnerability with a low management regime.

Dune managers are able, after a careful interpretation of the indices, to identify potential vulnerable areas and then initiate possible changes in their management strategy to compensate. However it must be noted that careful interpretation of the indices is needed since low protection indices do not necessarily mean inappropriate management strategies. These apparent ambiguities may be explained by detailed consideration of the checklist parameters especially the sediment supply.

For the checklist to give a true assessment of the dune system, the parameters do require individual weighting in order to give a true reflection of the site. Parameters such as sediment supply or visitor pressure, should be given a higher weighting than factors such as the number of owners or whether information boards are present. Due to this, the next step to the further honing of this checklist is to weight each parameter. Information regarding this, is being sent to various "dune experts". The results obtained will then allow the individual parameters to be weighted accordingly. Also some of the terms within the checklist need a tighter definition, for example parameter 8 (TABLE 1), just asks if there is "much", "none" or "some" seaweed on the upper beach. Due to the lack of quantification, the results could be open to variation. However it should be noted that despite these potential ambiguities, between different investigators completing a checklist, no significant variations have occured with the results obtained using this checklist (WILLIAMS. pers.comm.)

It has also been expressed that some managers feel that the checklist is a little too general to be of use in dealing with specific problems (JONES, pers.comm.). However when dune managers were approached in relation to completion of the checklist for the system under their care, many were unable to complete sections of it without help, as they lacked knowledge of the general details of their system! It was also suggested that elements such as species diversity and the presence of pollution on site should be included within the checklist, and further research might be profitably engaged here. Despite these misgivings the dune vulnerability checklist provides the most objective assessment of the dune environment to date, and as such should be considered as a valuable dune management tool.

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APPENDIX 1

RAW RESULTS

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Murray Mouth

Name of system: Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [✓]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [✓]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
	total score / percentage 16/32 = 50%					

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]
	total score / percentage 10/36 = 27.8					

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [ ]	>10 [✓]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [✓]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [✓]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [✓]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [ ]		small [✓]		large [ ]
	total score / percentage 22/48 = 45.8%					

MERTHYR MAWR

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [✓]	high [ ]
2.	Road access	none [ ]	moderate [✓] 2	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 18/56 = 32.1%

VULNERABILITY SCORE AND INDEX 66/172 = 38.4%

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [✓]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		

19/44 = 43.2%

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: Kinloch Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2.	Surface area of dunes (ha)	>500 [✓]		>100 [ ]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [✓]	>1 [ ]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [✓] 33M	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [✓] 19	5-9 [ ]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [✓] 30%		small [ ]		none [ ]
8.	Particle size in foredunes	____	____	____	____	____
	Compare particle size with index	____	____	____	____	____
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 11/32 = 34.4%

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ] → Limit HWM ?
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [✓]
5.	Dune cliff as % dune height	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [✓]
8.	Seaweed on upper beach	much [✓]		some [ ]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 27/36 = 75%

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ] Small new but dev. slow
2.	Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [✓]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [ ] 3ha →		some [✓]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [✓]	0 [ ] 60M
6.	% breaches with new dunes	>75 [✓]	>50 [ ]	>25 [ ]	>5 [ ]	0 [ ]
7.	% seaward dune front vegetated	>90 [✓]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [✓] 5ha		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [ ]		re-treat [✓] 30M
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ] but 1956 shown FOS (+Bulk

total score / percentage 17/48 = 35.4

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SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage 16/56 = 28.6%

VULNERABILITY SCORE AND INDEX 71/172 = 41.3%

SECTION E - RECENT PROTECTION MEASURES		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [ ]		all [✓]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [ ]		many [✓]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		

26/44 = 59.1%

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Crymlyn Burrows

Name of system: Location: Survey Date: Surveyor:

B. Hill

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [✓]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes	———	———	———	———	———
	Compare particle size with index	———	———	———	———	———
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
	total score / percentage	20/32 = 62.5%				

River creek sloping ... to SM ... dominated by B. Pcil ... to ... trend.

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [✓]
	total score / percentage	13/36 = 36.1				

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [✓]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [✓]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [ ]		none [✓]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]
	total score / percentage	23/45 = 47.0				

CRYMLYN

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [✓]	moderate [ ]	high [ ]
2.	Road access	none [✓]	moderate [ ]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage 4/56 = 7.1%

VULNERABILITY SCORE AND INDEX 60/172 = 34.9

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [✓]		some [ ]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [✓]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [✓]		some [ ]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		

18/44 = 40.9

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: **Location:** **Survey Date:** **Surveyor:**

Boglan.

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [✓]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [✓]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	———	———	———	———	———
	Compare particle size with index	———	———	———	———	———
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage

18/32 = 56.3

BAGLAN

SECTION B - CONDITION OF THE BEACH

1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [ ]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [✓]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage

12 / 36 = 33.3

SCORES>

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

		0	1	2	3	4
1.	% System surface unvegetated	<10 [ ]	>10 [ ]	>20 [✓]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [ ]	>20 [✓]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [✓]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [✓]	<5 [ ]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [✓]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [✓]		some [ ]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage

23 / 48 = 47.9

BAGLAN

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [✓]	high [ ]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [ ]	some [✓]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
6.	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [ ]	some [ ]	much [✓]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage

VULNERABILITY SCORE AND INDEX

V = 40·1

16/56 = 28·6

SECTION E - RECENT PROTECTION MEASURES

SCORES>

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [✓]		all [ ]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [ ]		some [ ]		many [✓]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [✓]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		str. [ ]

26/44 = 59·1

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: Location: Survey Date: Surveyor: Orwich

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [✓]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	✓	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [ ]	+3 [ ]

total score / percentage 19/32 = 59.4%

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 7/36 = 19.4

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [✓]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [ ]		none [✓]
9.	% impenetrable cover	some [✓]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 18/48 = 37.5

Oxwich

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [✓]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
6	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage 16/56 = 28·6

VULNERABILITY SCORE AND INDEX 60/172 = 34·9%

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [✓]		some [ ]		much [✓]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [✓]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [ ]		all [✓]
7.	Sand traps	few [✓]		some [✓]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		

24/44 = 54·5

Name of system: HILLEND Location: NORTH GOWER Survey Date: 28.11.93 Surveyor: NICOLA HOWE

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [✓]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [✓]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [✓]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	____	____	____	____	____
	Compare particle size with index	____	____	____	____	____
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [ ]	+3 [ ]

total score / percentage 19/32 = 59.4

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [✓]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [✓]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [ ]		many [✓]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [✓]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage 21/36 = 58.3

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [ ]	>10 [ ]	>20 [✓]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [ ]	>20 [✓]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [ ]		much [✓]
4.	Saltwater invasion of dunes	none [ ]		some [ ]		much [✓]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [✓]	<5 [ ]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [✓]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [✓]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [✓]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [ ]		re-treat [✓]
11.	Vegetation change since 1940	inc. [ ]		oscil. [ ]		decr. [✓]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 31/48 = 64.6

Hulland

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [ ]	high [✓]
	Paths incised	little [ ]	moderate [ ]	deep [✓]
7.	Commercial camping	little [ ]	some [ ]	much [✓]
8.	Dispersed camping	little [ ]	some [ ]	much [✓]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [✓] ✗ 1960's
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 30/56 = 53·6

VULNERABILITY SCORE AND INDEX = 58·7

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓] 1994
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [✓]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

25/44 = 56·8

LAUGHARNE

SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1. Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2. Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3. Length of dune coast (km)	>20 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	>.1 [ ]
4. Width of dune belt (km)	>5 [ ]	>2 [✓]	>1 [ ]	>.1 [ ]	<.1 [ ]
5. Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a. If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b. If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c. If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7. Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8. Particle size in foredunes	———	———	———	———	———
Compare particle size with index	———	———	———	———	———
Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
total score / percentage	18/32 = 56.3				

SECTION B - CONDITION OF THE BEACH					
1. Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2. Sand supply input	high [ ]		moderate [ ]		low [✓]
3. Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4. % foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [✓]	>50 [ ]	>75 [ ]
5. Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6. Breaches in seaward face	none [✓]		some [ ]		many [ ]
7. Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8. Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9. Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]
total score / percentage	13/36 = 36.1				

SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1. % System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2. Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3. Sand blown inland from system	little [✓]		some [ ]		much [ ]
4. Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5. % new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6. % breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7. % seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8. If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9. % impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10. Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11. Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12. Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]
total score / percentage	19/49 = 38.6				

LAUGHARNE

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [ ]
2.	Road access	none [ ]	moderate [✓]	good [ ]
3.	On dune driving	none [ ]	some [✓]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 10/56 = 18·6

VULNERABILITY SCORE AND INDEX 60/176 = 34·5

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [✓]		some [ ]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [✓]
3.	Controlled parking	none [ ]		some [✓]		all [ ]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

16/44 = 36·4

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: BROUGHTON Location: NORTH GOWER Survey Date: 28-11-93 Surveyor: NICOLA LOWE

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [✓]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [✓]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [✓]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [✓]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 19/32 = 59.4

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [✓]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [✓]	>25 [ ]	>50 [✓]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage 17/36 = 47.2

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [ ]	>5 [✓]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [✓]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [ ]		none [ ]
9.	% impenetrable cover	some [✓]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [ ]		re-treat [✓]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage = 21.2

BROUGHTON

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [✓]	high [ ]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [ ]	some [ ]	much [✓]
8.	Dispersed camping	little [ ]	some [✓]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 22/56 = 39.3

VULNERABILITY SCORE AND INDEX 73/172 = 42.4

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [✓]		all [ ]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [ ]		all [ ]
7.	Sand traps	few [✓]		some [✓]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

14/44 = 31.8

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: Whitford. Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓] 150 ha		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [✓]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [✓]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [✓] 15%		small [ ]		none [ ]
8.	Particle size in foredunes	____	____	____	____	____
	Compare particle size with index	____	____	____	✓	____
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 15/32 = 46.9%

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [✓]		moderate [ ]		low [ ]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 9/36 = 25%

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [✓]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [✓]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/✓ much [ ]
10.	Frontal change since 1940	advance [✓]		oscil. [ ]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [ ]		small [✓]		large [ ]

total score / percentage 22/48 = 45.8

10,000 km²
1h.
1 - 500 ha

3

All ridges
Active lake

whitefordl

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [✓]	moderate [ ]	high [ ]
2.	Road access	none [ ]	moderate [✓] /	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓] NNR	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓] farm	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [✓]

total score/percentage 10/56 = 17.9%

VULNERABILITY SCORE AND INDEX 56/172 = 32.6%

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [✓]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [✓]		some [ ]		all [✓]
4.	Horse riding controlled	none [✓]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [ ]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓]	NONE	some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		

14/44 = 31.8%

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: Pembrey Forest Location: Dyfed. Survey Date: 6th April 94 Surveyor: Mike Scott. - Forest Ranger.

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [✓]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes					
	Compare particle size with index	Not known.				
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 24/32 = 75%.

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage 10/36 = 27.8

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [✓]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [✓]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [✓]		some [ ]		none [ ]
9.	% impenetrable cover	some [✓]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 9/48 = 18.8

PEMBREY

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [✓]	moderate [ ]	high [ ]
2.	Road access	none [✓]	moderate [ ]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓] None	some [ ]	much [ ]
8.	Dispersed camping	little [✓] None	some [ ]	much [ ]
9.	Housing	little [✓] None	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓] Forest Enterprise	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage 2/56 = 2.1

VULNERABILITY SCORE AND INDEX 47/172 = 27.3

SECTION E - RECENT PROTECTION MEASURES		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓] None		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

17/44 = 38.6

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: PENDARD. Location: Survey Date: 15/6/94 Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [✓]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [✓]	>1 [ ]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [✓]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
	total score / percentage 17/32 = 53.1					

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]
	total score / percentage 17/36 = 47.2					

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [ ]		some [✓]		much [✓]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [✓]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [✓]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]
	total score / percentage 20/48 = 41.7					

KENNARD

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [ ]
2.	Road access	none [ ]	moderate [ ]	good [ ]
3.	On dune driving	none [ ]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [ ]	high [ ]
	Paths incised	little [ ]	moderate [ ]	deep [ ]
7.	Commercial camping	little [ ]	some [ ]	much [ ]
8.	Dispersed camping	little [ ]	some [ ]	much [ ]
9.	Housing	little [ ]	some [ ]	much [ ]
10.	Owners	one [ ]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [ ]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [ ]	large [ ]

total score/percentage = 35.7

VULNERABILITY SCORE AND INDEX = 42.5

	SECTION E - RECENT PROTECTION MEASURES	0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [ ]
4.	Horse riding controlled	none [ ]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [ ]
6.	Managed paths	none [ ]		some [ ]		all [ ]
7.	Sand traps	few [ ]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		

23 - 52

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: PENDINE Location: Survey Date: 16/10 94 Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [✓]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [✓]		small [ ]		none [ ]
8.	Particle size in foredunes	___	___	___	___	___
	Compare particle size with index	___	___	___	___	___
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 18/32 = 56.3

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [✓]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 10/36 = 27.8

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [✓]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [✓]		some [ ]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 16/48 = 33.3

PENDING

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [ ]
2.	Road access	none [ ]	moderate [ ]	good [ ]
3.	On dune driving	none [ ]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [ ]	high [ ]
	Paths incised	little [ ]	moderate [ ]	deep [ ]
7.	Commercial camping	little [ ]	some [ ]	much [ ]
8.	Dispersed camping	little [ ]	some [ ]	much [ ]
9.	Housing	little [ ]	some [ ]	much [ ]
10.	Owners	one [ ]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [ ]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [ ]	large [ ]

total score/percentage S/ = 14·3

VULNERABILITY SCORE AND INDEX S/ = 30·2

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [ ]
4.	Horse riding controlled	none [ ]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [ ]
6.	Managed paths	none [ ]		some [ ]		all [ ]
7.	Sand traps	few [ ]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		

S/ = 36·2

~~COASTAL SAND DUNE ASSESSMENT SYSTEM~~

Name of system: STACKPOLE. **Location:** **Survey Date:** 8.3.94 **Surveyor:** R. Ellis + RS HANCOCK.

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [✓]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [ ]	>.1 [✓]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [ ]	<.1 [✓]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage

18/32 = 56.3

STACKPOLE

SECTION B - CONDITION OF THE BEACH

1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [ ]		>.1 [ ]	>.05 [ ]		<.05 [✓]	
2.	Sand supply input	high [ ]			moderate [ ]			low [✓]	
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]		>5 [ ]	>25 [ ]		>50 [ ]	
4.	% foredunes cliffed by the sea	0 [✓]	<25 [ ]		>25 [ ]	>50 [ ]		>75 [ ]	
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]		>25 [ ]	>50 [ ]		>75 [ ]	
6.	Breaches in seaward face	none [✓]			some [ ]			many [ ]	
7.	Width of breaches in seaward face	<2 [✓]			2-10 [ ]			>10 [ ]	
8.	Seaweed on upper beach	much [ ]			some [✓]			none [ ]	
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]			some [ ]			neg [✓]	

total score / percentage 14/36 = 38.9

SCORES>

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

		0	1	2	3	4
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [ ]		much [✓]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [ ]		none [✓]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage

25/48 = 52.1

STACKPOLE

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [✓]	moderate [ ]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
6.	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 10/56 = 17.9.

VULNERABILITY SCORE AND INDEX 67/172 = 38.9

SECTION E - RECENT PROTECTION MEASURES

SCORES>

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [✓]
3.	Controlled parking	none [✓]		some [ ]		all [ ]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [✓]		some [ ]		all [ ]
6.	Managed paths	none [✓]		some [ ]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		str. [✓]

13/44 = 29.5

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: BROADHAVEN SOUTH **Location:** SR978940 **Survey Date:** 8.3.94 **Surveyor:** RICHARD ELLIS & R S HAYCOCK

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [ ]	>.1 [✓]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [ ]	<.1 [✓]
5.	Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	0.3mm				
	Compare particle size with index					
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 21/32 = 65.6

There is a wet slack area, but it is morphologically the result of sand-quarrying 20+ years ago & not a natural feature!

BROADHAVEN

SECTION B · CONDITION OF THE BEACH

1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [✓]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 16/35 = 44·4

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

SCORES>

		0	1	2	3	4
1.	% System surface unvegetated	<10 [ ]	>10 [ ]	>20 [✓]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [✓]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/much [ ]
10.	Frontal change since 1940	advance [✓]		oscil. [ ]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 21/48 = 43·8

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [ ]	high [✓]
6.	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ] NONE
8.	Dispersed camping	little [ ]	some [ ]	much [ ]
9.	Housing	little [ ]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 16/56 = 28.6

VULNERABILITY SCORE AND INDEX 74/172 = 43

Camping in adjacent fields causing unofficial paths along desire lines.

SECTION E - RECENT PROTECTION MEASURES		0	1	2	3	4
		SCORES>				
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [ ]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [✓]		some [ ]		all [ ]
6.	Managed paths	none [✓]		some [ ]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		str. [✓]

10/44 = 22.7

WNR 5551

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: FRESHWATER WEST Location: SR885000 Survey Date: 8.3.94 Surveyor: RICHARD ELLIS

SECTION A - SITE AND DUNE MORPHOLOGY	0	1	2	3	4
SCORES>					
1. Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2. Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3. Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4. Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [ ]	<.1 [✓]
5. Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a. If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [✓]	1 [ ]
6b. If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c. If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7. Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8. Particle size in foredunes					
Compare particle size with index	0.23 mm				
Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage

20/32 = 62.5

wet slacks in hinterland — partly result of former quarrying

FRESHWATER WEST

SECTION B · CONDITION OF THE BEACH

1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [ ]	>.1 [ ]	>.05 [✓]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage 16/36 = 44.4

SCORES>

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

		0	1	2	3	4
1.	% System surface unvegetated	<10 [ ]	>10 [ ]	>20 [ ]	>40 [✓]	>75 [ ]
2.	Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [✓]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [ ]		much [✓]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover ?	some [ ]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [✓]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 24/48 = 50.2

FRESHWATER WEST

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [ ]	some [✓]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
6.	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [✓]	much [ ] – NONE
8.	Dispersed camping	little [ ]	some [✓]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ] NONE
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 26/56 = 46.4

VULNERABILITY SCORE AND INDEX 88/172 = 51.2

SECTION E - RECENT PROTECTION MEASURES

		SCORES> 0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [✓]		all [ ]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [✓]		some [ ]		all [ ]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [ ]		some [✓]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		str. [✓]

15/44 = 34.1

Name of system:	Location:	Survey Date:	Surveyor:
FRAINSLAKE DUNES / FRAINSLAKE BURROWS	SR890985	8.3.94	R ECCLS

SECTION A - SITE AND DUNE MORPHOLOGY		SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [ ]	<.1 [✓]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes	____	____	____	____	____
	Compare particle size with index	NOT DONE	____	____	____	____
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage

18/32 = 56.3

BROWNSLADE

SECTION B · CONDITION OF THE BEACH

1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [ ]	>.1 [ ]	>.05 [✓]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage 12/36 = 33.3

SCORES>

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

		0	1	2	3	4
1.	% System surface unvegetated	<10 [✓]	>10 [✓]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [✓]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [✓]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [✓]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none [✓] much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage

23/48 = 47.9

BROWNSEA DE

MOD and !

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [✓]	moderate [ ]	high [ ]
2.	Road access	none [✓]	moderate [ ]	good [ ]
3.	On dune driving	none [ ]	some [✓]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
6.	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [-]	some [ ]	much [ ] none
8.	Dispersed camping	little [-]	some [ ]	much [ ] none
9.	Housing	little [-]	some [ ]	much [ ] none
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [ ] (MOD)
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [ ]	much [✓]
14.	Rabbit population	small [ ]	moderate [ ]	large [✓]

total score/percentage 10/56 = 17.9

VULNERABILITY SCORE AND INDEX 63/172 = 36.6

SECTION E - RECENT PROTECTION MEASURES

SCORES>

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [✓] 100%!
3.	Controlled parking	none [✓]		some [ ]		all [ ]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [✓]		all [ ] (MOD)
6.	Managed paths	none [✓]		some [ ]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		str. [✓] SSSI etc

44/44 = 31.8

TABLE 1: COSTAL SAND DUNE VULNERABILITY CHECKLIST

(See background notes, Appendix 1)

Name of system: Tenby **Location:** **Survey Date:** **Surveyor:**

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>.1 [ ]	>.1 [✓]	<.1 [ ]
+ 5.	Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
− 7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes Compare particle size with index	☐	☐	☐	☐	☐
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
	total score / percentage 23 / 32 = 71.88					

	SECTION B - CONDITION OF THE BEACH					
+ 1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
+ 3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [✓]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]
	total score / percentage 16 / 36 = 44.4					

Tenby

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m	SCORES> 0	1	2	3	4
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
– 2.	Blowouts as % of system area	<5 [ ]	>5 [✓]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
– 4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [✓]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [✓]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
– 9.	% impenetrable cover	some [✓]		little [ ]		~~none~~/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 13/48 = 35.4

	SECTION D - PRESSURE OF USE			
– 1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
– 2.	Road access	none [ ]	moderate [ ]	good [✓]
– 3.	On dune driving	none [ ]	some [✓]	much [ ]
– 4.	Horse riding	none [✓]	some [ ]	much [ ]
– 5.	Path network density	low [ ]	medium [✓]	high [ ]
– 6.	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [✓]
12.	Commerical/random extraction	none [✓]	some [ ]	much [ ]
– 13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
– 14.	Rabbit population	small [✓]	mdoerate [ ]	large [ ]

total score/percentage

VULNERABILITY SCORE AND INDEX 13 — 1039

74/176 = 42.5

TENBY

	SECTION E - RECENT PROTECTION MEASURES	SCORES> 0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [✓]		all [ ]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		str. [ ]

19/44 = 43·2

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: Yyngya Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [✓]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes	___	___	___	___	___
	Compare particle size with index				✓	
		___	___	___	___	___
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [ ]	+3 [ ]
	total score / percentage 22 = 68.8%					

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [✓]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]
	total score / percentage 19 = 52.8%					

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [ ]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [✓]		much [ ]
4.	Saltwater invasion of dunes	none [ ]		some [✓]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [✓]	>5 [ ]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [✓]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [ ]		re-treat [✓]
11.	Vegetation change since 1940	inc. [ ]		oscil. [ ]		decr. [✓]
12.	Relic quarries in frontal (200m)	none [ ]		small [ ]		large [✓]
	total score / percentage 38 = 79.2%					

VNYSLAS

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [/]
2.	Road access	none [ ]	moderate [ ]	good [/]
3.	On dune driving	none [/]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [/]	much [ ]
5.	Path network density	low [ ]	medium [/]	high [ ]
	Paths incised	little [ ]	moderate [/]	deep [ ]
7.	Commercial camping	little [/]	some [ ]	much [ ]
8.	Dispersed camping	little [/]	some [ ]	much [ ]
9.	Housing	little [/]	some [ ]	much [ ]
10.	Owners	one [/]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [/]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [/]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [/]	much [ ]
14.	Rabbit population	small [ ]	moderate [/]	large [ ]

total score/percentage 18 = 32.1%

VULNERABILITY SCORE AND INDEX

SECTION E - RECENT PROTECTION MEASURES		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [/]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [/]
3.	Controlled parking	none [ ]		some [ ]		all [/]
4.	Horse riding controlled	none [ ]		some [ ]		all [/]
5.	On dune driving controlled	none [ ]		some [ ]		all [/]
6.	Managed paths	none [ ]		some [/]		all [ ]
7.	Sand traps	few [/]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [/]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [/]		many [ ]
10.	If marine erosion - protection work?	neg. [/]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [/]		

27 = 61.4

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: TYWYN - ABERDOVEY Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [✓]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [ ]
8.	Particle size in foredunes	____	____	____	____	____
	Compare particle size with index	____	____	____	____	____
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 43/99 = 43.8

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [✓]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 18/36 = 50

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [✓]	>5 [ ]	<5 [ ]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [✓]	>5 [ ]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [✓]		some [ ]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 10/48 = 20.8

TYWYN- ABERDOVEY

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [✓]	high [ ]
2.	Road access	none [✓]	moderate [ ]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 10/56 = 17.9

VULNERABILITY SCORE AND INDEX 52/126 = 29.9

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [ ]		some [ ]		many [✓]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [✓]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

18/45 = 40.9

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: MORFA DYFFRYN | Location: SH560 250 | Survey Date: 19/11/93 | Surveyor: J G Neale (warden - ccw)

SCORES>

SECTION A - SITE AND DUNE MORPHOLOGY	0	1	2	3	4
1. Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2. Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3. Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4. Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5. Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a. If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [✓]	2 [ ]	1 [ ]
6b. If plastered to slope - slope steepness	moderate [ ]		gentle [✓]		steep [ ]
6c. If perched on cliff - cliff height (m) (damp)	<2 [ ]		2-5 [ ]		>5 [ ]
7. Relative total area of wet slacks	moderate [✓]		small [ ]		none [ ]
8. Particle size in foredunes	----	----	----	----	----
Compare particle size with index	----	----	----	----	----
Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 19/32 = 59.4

SECTION B - CONDITION OF THE BEACH					
1. Width of inter-tidal zone km	>.5 [ ]	>.2 [ ]	>.1 [✓]	>.05 [ ]	<.05 [ ]
2. Sand supply input	high [ ]		moderate [ ]		low [✓]
3. Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [✓]	>25 [ ]	>50 [ ]
4. % foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [✓]	>75 [ ]
5. Dune cliff as % dune height	0 [ ]	<25 [ ]	>25 [✓]	>50 [ ]	>75 [ ]
6. Breaches in seaward face	none [ ]		some [ ]		many [✓]
7. Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8. Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9. Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 25/36 = 69.4

SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1. % System surface unvegetated	<10 [ ]	>10 [ ]	>20 [ ]	>40 [✓]	>75 [ ]
2. Blowouts as % of system area	<5 [ ]	>5 [ ]	>10 [ ]	>20 [✓]	>40 [ ]
3. Sand blown inland from system	little [ ]		some [ ]		much [✓]
4. Saltwater invasion of dunes	none [ ]		some [✓]		much [ ]
5. % new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6. % breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7. % seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [✓]	>10 [ ]	<10 [ ]
8. If recent sand deposition assess colonisation by marram	much [ ]		some [ ]		none [✓]
9. % impenetrable cover	some [ ]		little [ ]		none/✓ much [ ]
10. Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [✓] (recent)
11. Vegetation change since 1940	inc. [ ]		oscil. [ ]		decr. [✓]
12. Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 36/48 = 75

MORFA DYFFRYN.

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [ ]	some [✓]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [ ]	some [ ]	much [✓]
8.	Dispersed camping	little [ ]	some [✓]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [ ]	some [✓]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [ ]	moderate [ ]	large [✓]

total score/percentage 32/56 = 57.1

VULNERABILITY SCORE AND INDEX 112/172 = 65.1

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [✓]		all [ ]
4.	Horse riding controlled	none [ ]		some [✓]		all [ ]
5.	On dune driving controlled	none [ ]		some [✓]		all [ ]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [ ]		some [✓]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [ ]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

18/44 = 40.9

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: MORFA HARLECH | Location: SH560350 | Survey Date: 19/11/93 | Surveyor: J G Neale (WARDEN-CCW)

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [✓]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [✓]		small [ ]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 15/32 = 46.9

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [✓]		moderate [ ]		low [ ]
3.	Pebble cover as % of surface	0 [ ]	<5 [✓]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [✓]		some [ ]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [✓]		some [ ]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

was much but now ↗ storm dispersed in 91

total score / percentage 6/36 = 16.7

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [ ]	>5 [✓]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [✓]	<5 [ ]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [✓]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [✓]		oscil. [ ]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 10/48 = 20.7

MORFA HARLECH.

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [✓]	moderate [ ]	high [ ]
2.	Road access	none [ ]	moderate [✓]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [✓]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 10/56 = 17.9

VULNERABILITY SCORE AND INDEX 41/172 = 23.8

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [✓]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [✓]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [✓]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [ ]		some [✓]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [ ]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

24/44 = 54.5

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: MORFA BYCHAN Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]

total score / percentage 17/32 = 53.1

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [✓]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [ ]		>10 [✓]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]

total score / percentage 18/36 = 50

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [ ]		some [✓]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [✓]	>5 [ ]	<5 [ ]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [✓]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 17/48 = 35.4

MORFA BYCHAN

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [ ]	some [✓]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [ ]	moderate [ ]	deep [✓]
7.	Commercial camping	little [ ]	some [ ]	much [✓]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [✓]	large [ ]

total score/percentage 30/56 = 53.6

VULNERABILITY SCORE AND INDEX 82/74 = 47.1

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [✓]		some [ ]		much [ ]
2.	% area with restricted access	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [✓]		some [ ]		all [ ]
4.	Horse riding controlled	none [ ]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [✓]		all [ ]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		

6 / 44 = 13.6

25.3hec ✓ Ilbe.jock – Nels.

TABLE 1: COSTAL SAND DUNE VULNERABILITY CHECKLIST

(See background notes, Appendix 1)

Name of system: **Location:** **Survey Date:** **Surveyor:**

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [ ]		long [✓]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>.1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [✓]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [✓]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes Compare particle size with index	☐	☐	☐	☑	☐
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [ ]	+3 [ ]

total score / percentage 27/32 = 84.4

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [✓]
5.	Dune cliff as % dune height	0 [ ]	<25 [ ]	>25 [ ]	>50 [✓]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage 18/36 = 50

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m	SCORES> 0	1	2	3	4
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [✓]	<5 [ ]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [✓]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [✓]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [✓]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage 12/48 = 25

	SECTION D - PRESSURE OF USE				
1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]	
2.	Road access	none [ ]	moderate [✓]	good [ ]	
3.	On dune driving	none [✓]	some [ ]	much [ ]	
4.	Horse riding	none [ ]	some [✓]	much [ ]	
5.	Path network density	low [ ]	medium [✓]	high [ ]	
6.	Paths incised	little [ ]	moderate [✓]	deep [ ]	
7.	Commercial camping	little [✓]	some [ ]	much [ ]	
8.	Dispersed camping	little [✓]	some [ ]	much [ ]	
9.	Housing	little [✓]	some [ ]	much [ ]	
10.	Owners	one [✓]	some [ ]	many [ ]	
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [ ]	
12.	Commerical/random extraction	none [✓]	some [ ]	much [ ]	
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]	
14.	Rabbit population	small [ ]	mdoerate [✓]	large [ ]	

total score/percentage 14/56 = 25

VULNERABILITY SCORE AND INDEX

71/172 = 41.3

	SECTION E - RECENT PROTECTION MEASURES	SCORES> 0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [✓]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [✓]		all [ ]
5.	On dune driving controlled	none [ ]		some [✓]		all [ ]
6.	Managed paths	none [ ]		some [ ]		all [✓]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [✓]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		str. [ ]

22/44 = 50

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: MORFA DINLLE Location: Survey Date: Surveyor:

		SCORES> 0	1	2	3	4
	SECTION A - SITE AND DUNE MORPHOLOGY					
1.	Orthogonal fetch	short [✓]		medium [ ]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [ ]		<100 [✓]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [✓]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [✓]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [✓]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes	———	———	———	———	———
	Compare particle size with index	———	———	———	———	———
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
	total score / percentage 18/32 = 56.6					
	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [✓]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [✓]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [✓]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [✓]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [✓]		some [ ]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]
	total score / percentage 19/36 = 57.8					
	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [ ]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [ ]	0 [✓]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [ ]	0 [✓]
7.	% seaward dune front vegetated	>90 [✓]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]
	total score / percentage 22/48 = 45.8					

MORFA DINLLE

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [✓]	high [ ]
2.	Road access	none [ ]	moderate [✓]	good [ ]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [✓]	some [ ]	much [ ]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓] ½ ½ →	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [ ]	moderate [ ]	large [✓]

total score/percentage 14/56 = 25

VULNERABILITY SCORE AND INDEX 73/174 = 42·0

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [✓]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [✓]		some [ ]		all [ ]
7.	Sand traps	few [✓]		some [ ]		many [ ]
8.	Planting on mobile areas (%)	0 [✓]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [✓]		some [ ]		many [ ]
10.	If marine erosion - protection work?	neg. [✓]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [ ]		

17/44 = 38·6

COASTAL SAND DUNE VULNERABILITY CHECKLIST

NEWBOROUGH WARREN / YNYS LLANDDWYN N.N.R.

Name of system: Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [X]		long [ ]
2.	Surface area of dunes (ha)	>500 [X]		>100 [ ]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [X]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [X]	>1 [ ]	>.1 [ ]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [X]	>10 [ ]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [X]	2 [ ]	1 [ ]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [X]		small [ ]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index	----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [X]	+3 [ ]

RIGHTANGLED TO PREVAILING WIND

total score / percentage 10/32 = 31·3

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [ ]	>.2 [X]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [X]		low [ ]
3.	Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [X]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [X]	>50 [ ]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [X]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [X]		many [ ]
7.	Width of breaches in seaward face	<2 [ ]		2-10 [X]		>10 [ ]
8.	Seaweed on upper beach	much [X]		some [ ]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [X]		neg [ ]

total score / percentage 14/36 = 38·9

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [ ]	>10 [X]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [X]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [ ]		some [X]		much [ ]
4.	Saltwater invasion of dunes	none [X]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [X]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [X]	>5 [ ]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [X]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [X]		none [ ]
9.	% impenetrable cover	some [X]		little [ ]		none/ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [ ]		re-treat [X]
11.	Vegetation change since 1940	inc. [X]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [X]		small [ ]		large [ ]

total score / percentage 16/48 = 33·3

NEWBOROUGH

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [X]	high [ ]
2.	Road access	none [ ]	moderate [X]	good [ ]
3.	On dune driving	none [X]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [X]	much [ ]
5.	Path network density	low [ ]	medium [X]	high [ ]
	Paths incised	little [ ]	moderate [X]	deep [ ] *
7.	Commercial camping	little [X]	some [ ]	much [ ]
8.	Dispersed camping	little [X]	some [ ]	much [ ]
9.	Housing	little [X]	some [ ]	much [ ]
10.	Owners	one [ ]	some [X]	many [ ]
11.	Main owner/manager	protection agencies [X]	public [ ]	priv. [ ]
12.	Commercial/random extraction	none [X]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [ ]	some [X]	much [ ]
14.	Rabbit population	small [X]	moderate [ ]	large [ ]

total score/percentage 14/56 = 25

VULNERABILITY SCORE AND INDEX

54/172 = 31.4

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [ ]		much [X]
2.	% area with restricted access	0 [ ]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [X]
3.	Controlled parking	none [ ]		some [ ]		all [X]
4.	Horse riding controlled	none [ ]		some [ ]		all [X]
5.	On dune driving controlled	none [ ]		some [ ]		all [X]
6.	Managed paths	none [ ]		some [ ]		all [X]
7.	Sand traps	few [ ]		some [X]		many [ ]
8.	Planting on mobile areas (%)	0 [X]	<10 [ ]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [X]		many [ ]
10.	If marine erosion - protection work?	neg. [X]		some [ ]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [X]		

30/56 = 53.6

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: CONWAY Location: Survey Date: Surveyor:

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [ ]	>10 [ ]	>5 [ ]	>1 [✓]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [✓]	>5 [ ]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [ ]		none [✓]
8.	Particle size in foredunes	———	———	———	———	———
	Compare particle size with index	———	———	———	———	———
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [✓]	+3 [ ]
	total score / percentage			68.8		

	SECTION B - CONDITION OF THE BEACH					
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [ ]		low [✓]
3.	Pebble cover as % of surface	0 [ ]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [✓]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [ ]	>75 [✓]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
7.	Width of breaches in seaward face	<2 [✓]		2-10 [ ]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [ ]		none [✓]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [ ]		neg [✓]
	total score / percentage			63.9		

	SECTION C - SURFACE CHARACTER OF SEAWARD 200m					
1.	% System surface unvegetated	<10 [✓]	>10 [ ]	>20 [ ]	>40 [ ]	>75 [ ]
2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [✓]		some [ ]		much [ ]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [✓]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [✓]	0 [ ]
7.	% seaward dune front vegetated	>90 [✓]	>60 [ ]	>30 [ ]	>10 [ ]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/ much [✓]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [ ]		oscil. [✓]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]
	total score / percentage			33.3		

CONWAY

SCORES>

SECTION D - PRESSURE OF USE

1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [✓]	some [ ]	much [ ]
5.	Path network density	low [✓]	medium [ ]	high [ ]
	Paths incised	little [✓]	moderate [ ]	deep [ ]
7.	Commercial camping	little [ ]	some [ ]	much [✓]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [✓]	some [ ]	many [ ]
11.	Main owner/manager	protection agencies [ ]	public [✓]	priv. [ ]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage 14/56 = 25

VULNERABILITY SCORE AND INDEX 75/174 = 43.1

SECTION E - RECENT PROTECTION MEASURES

		0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [ ]		some [ ]		all [✓]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [ ]		all [✓]
7.	Sand traps	few [ ]		some [ ]		many [✓]
8.	Planting on mobile areas (%)	0 [ ]	<10 [ ]	>10 [ ]	>25 [✓]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [✓]		moderate [ ]		

30/44 = 68.2

COASTAL SAND DUNE VULNERABILITY CHECKLIST

Name of system: **Location:** **Survey Date:** **Surveyor:**

	SECTION A - SITE AND DUNE MORPHOLOGY	SCORES> 0	1	2	3	4
1.	Orthogonal fetch	short [ ]		medium [✓]		long [ ]
2.	Surface area of dunes (ha)	>500 [ ]		>100 [✓]		<100 [ ]
3.	Length of dune coast (km)	>20 [✓]	>10 [✓]	>5 [ ]	>1 [ ]	>.1 [ ]
4.	Width of dune belt (km)	>5 [ ]	>2 [ ]	>1 [ ]	>.1 [✓]	<.1 [ ]
5.	Maximum height of dunes (m)	>25 [ ]	>10 [ ]	>5 [✓]	>1 [ ]	<1 [ ]
6a.	If ridged - number of major ridges	>10 [ ]	5-9 [ ]	3-4 [ ]	2 [ ]	1 [✓]
6b.	If plastered to slope - slope steepness	moderate [ ]		gentle [ ]		steep [ ]
6c.	If perched on cliff - cliff height (m)	<2 [ ]		2-5 [ ]		>5 [ ]
7.	Relative total area of wet slacks	moderate [ ]		small [✓]		none [ ]
8.	Particle size in foredunes	----	----	----	----	----
	Compare particle size with index				✓	
		----	----	----	----	----
	Phi sizes	=<-1 [ ]	0 [ ]	+1 [ ]	+2 [ ]	+3 [ ]

total score / percentage

17/32 = 53.1%

PRESTATYN

SECTION B - CONDITION OF THE BEACH

		0	1	2	3	4
1.	Width of inter-tidal zone km	>.5 [✓]	>.2 [ ]	>.1 [ ]	>.05 [ ]	<.05 [ ]
2.	Sand supply input	high [ ]		moderate [✓]		low [ ]
3.	Pebble cover as % of surface	0 [✓]	<5 [ ]	>5 [ ]	>25 [ ]	>50 [ ]
4.	% foredunes cliffed by the sea	0 [ ]	<25 [ ]	>25 [ ]	>50 [✓]	>75 [ ]
5.	Dune cliff as % dune height	0 [ ]	<25 [✓]	>25 [ ]	>50 [ ]	>75 [ ]
→ 6.	Breaches in seaward face	none [ ]		some [✓]		many [ ]
→ 7.	Width of breaches in seaward face	<2 [ ]		2-10 [✓]		>10 [ ]
8.	Seaweed on upper beach	much [ ]		some [✓]		none [ ]
9.	Colonisation by vegetation in zone between dune face and HWSM	much [ ]		some [✓]		neg [ ]

total score / percentage

14/36 = 38.9%

SCORES>

SECTION C - SURFACE CHARACTER OF SEAWARD 200m

		0	1	2	3	4
→ 1.	% System surface unvegetated	<10 [ ]	>10 [✓]	>20 [ ]	>40 [ ]	>75 [ ]
→ 2.	Blowouts as % of system area	<5 [✓]	>5 [ ]	>10 [ ]	>20 [ ]	>40 [ ]
3.	Sand blown inland from system	little [✓]		some [ ]		much [ ]
4.	Saltwater invasion of dunes	none [ ]		some [ ]		much [✓]
5.	% new dunes along seaward edge	>50 [ ]	>25 [ ]	>5 [ ]	<5 [✓]	0 [ ]
6.	% breaches with new dunes	>75 [ ]	>50 [ ]	>25 [ ]	>5 [✓]	0 [ ]
7.	% seaward dune front vegetated	>90 [ ]	>60 [ ]	>30 [ ]	>10 [✓]	<10 [ ]
8.	If recent sand deposition assess colonisation by marram	much [ ]		some [✓]		none [ ]
9.	% impenetrable cover	some [ ]		little [ ]		none/✓ much [ ]
10.	Frontal change since 1940	advance [ ]		oscil. [✓]		re-treat [ ]
11.	Vegetation change since 1940	inc. [✓]		oscil. [ ]		decr. [ ]
12.	Relic quarries in frontal (200m)	none [✓]		small [ ]		large [ ]

total score / percentage

22/48 = 45.8%

PRESTATYN

	SECTION D - PRESSURE OF USE	0	2	4
1.	Visitor pressure	low [ ]	moderate [ ]	high [✓]
2.	Road access	none [ ]	moderate [ ]	good [✓]
3.	On dune driving	none [✓]	some [ ]	much [ ]
4.	Horse riding	none [ ]	some [✓]	much [ ]
5.	Path network density	low [ ]	medium [✓]	high [ ]
6.	Paths incised	little [ ]	moderate [✓]	deep [ ]
7.	Commercial camping	little [ ]	some [ ]	much [✓]
8.	Dispersed camping	little [✓]	some [ ]	much [ ]
9.	Housing	little [✓]	some [ ]	much [ ]
10.	Owners	one [ ]	some [✓]	many [ ]
11.	Main owner/manager	protection agencies [✓]	public [ ]	priv. [✓]
12.	Commercial/random extraction	none [✓]	some [ ]	much [ ]
13.	Grazing by cattle/sheep/goats	none [✓]	some [ ]	much [ ]
14.	Rabbit population	small [✓]	moderate [ ]	large [ ]

total score/percentage 24/56 = 42.9

VULNERABILITY SCORE AND INDEX ~~77~~ /172

	SECTION E - RECENT PROTECTION MEASURES	SCORES> 0	1	2	3	4
1.	Surveillance and maintenance	none [ ]		some [✓]		much [ ]
2.	% area with restricted access	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
3.	Controlled parking	none [ ]		some [ ]		all [✓]
4.	Horse riding controlled	none [✓]		some [ ]		all [ ]
5.	On dune driving controlled	none [ ]		some [ ]		all [✓]
6.	Managed paths	none [ ]		some [✓]		all [ ]
7.	Sand traps	few [ ]		some [✓]		many [ ]
8.	Planting on mobile areas (%)	0 [ ]	<10 [✓]	>10 [ ]	>25 [ ]	>50 [ ]
9.	Information boards	none [ ]		some [✓]		many [ ]
10.	If marine erosion - protection work?	neg. [ ]		some [✓]		much [ ]
11.	Protection by legislation	weak [ ]		moderate [✓]		str. [ ]

22/44 = 50

APPENDIX 2

NOTES FOR USE WITH THE COASTAL SAND DUNE VULNERABILITY CHECKLIST (TABLE 1)

NOTES FOR USE WITH THE COASTAL SAND DUNE VULNERABILITY CHECKLIST.

The items included in the checklist have been grouped for convenience of use in the field, making it possible, for example to record all the important beach zone characteristics within one section of the list. Many of the items are self-explanatory; the following notes provide elucidation where necessary.

Section A

This section is concerned with the relationship of the dunes to constructive and destructive agencies, to the inertia of the system and to site factors which may influence the resilience of the system. Items 1-5 are largely self-explanatory. Question 5: where a dune is deposited over a rising substrate, the maximum height above that substrate should be entered. Questions 6a to 6c: these alternatives to allow for different types of dune system. The term 'plastered dunes' (dunes plaquees) is used to describe sand accumulated on a seaward facing slope, usually without distinct ridges. The term 'perched' refers to dunes which are separated from the beach by a substrate cliff.

Section B

Question 1: width of the inter-tidal zone can be assessed from topographic maps.

Question 6: breaches in the seaward face refers to both natural and anthropogenic activity. If there are no breaches then question 7, category 2m should be applied. Colonisation by vegetation in the zone between the dune face and HWSM. (Question 9) is highly significant

and has not been restricted to colonization by a particular species.

Section C

Analysis has been restricted to the seaward 200m because this area is the most vulnerable to human and natural degradation. Questions 1 and 2 are best assessed from high vantage points, and with reference to aerial photographs where available. Question 6: breaches in the dunes were recorded in section B,Q.6., but it is clearly important to record natural repair by the accumulation of new dunes in the breaches. Question 7: vegetation on the face of the dune should not be confused with vegetation between the dune front and HWSM (Section B,Q.9). Question 10: colonisation of a dune field by impenetrable cover (eg Sea Buckthorn) may become so extensive that it changes the whole character of the dune field, becoming 'non-dune'. Clearly some impenetrable cover will reduce dune vulnerability without grossly affecting dune character. Questions 10 and 11: 1940 was selected because of the severe impact on many dunes of defensive works and the use of dunes as military training grounds. Question 12: many relict sand quarries have been sited too near to the most seaward ridge, resulting in overtopping and inundation.

Section D

These questions on public pressure are largely self-explanatory. In Question 7, Commercial Camping can refer to holiday chalet camps as well as tent and caravan/mobile home sites. Dispersed camping (Question 8) refers to 'camping sauvage' outside recognised sites. Question 9: some housing does occur in dune fields, but this question also refers to housing in the immediate hinterland of the dune. In Question 11 bodies such as County and District Councils or Departments would be regarded as public agencies. Question 12: some commercial extraction may be evident in the dunes, but removal of sand by private individuals should also be recorded. Question 14: the density of rabbit population can be assessed from depositionary evidence!

Section E

Again these questions are straight forward since most protection measures effectively advertise themselves. Question 11 is the least obvious. Generally speaking, strong protective legislation will be associated with, for example, Sites of Special Scientific Interest (SSSI's) or with the Conservatoire de I' Espace Littoral in France. Management by some Local Authorities or Departments might generally be backed by less strong legislation, and weak legislation might be expected where dunes are owned by a variety of individual land-owners. Care should be taken to determine the degree of such legislative protection since the examples quoted above are only broad generalisations.